Vascularized bone of the fibula and iliac crest

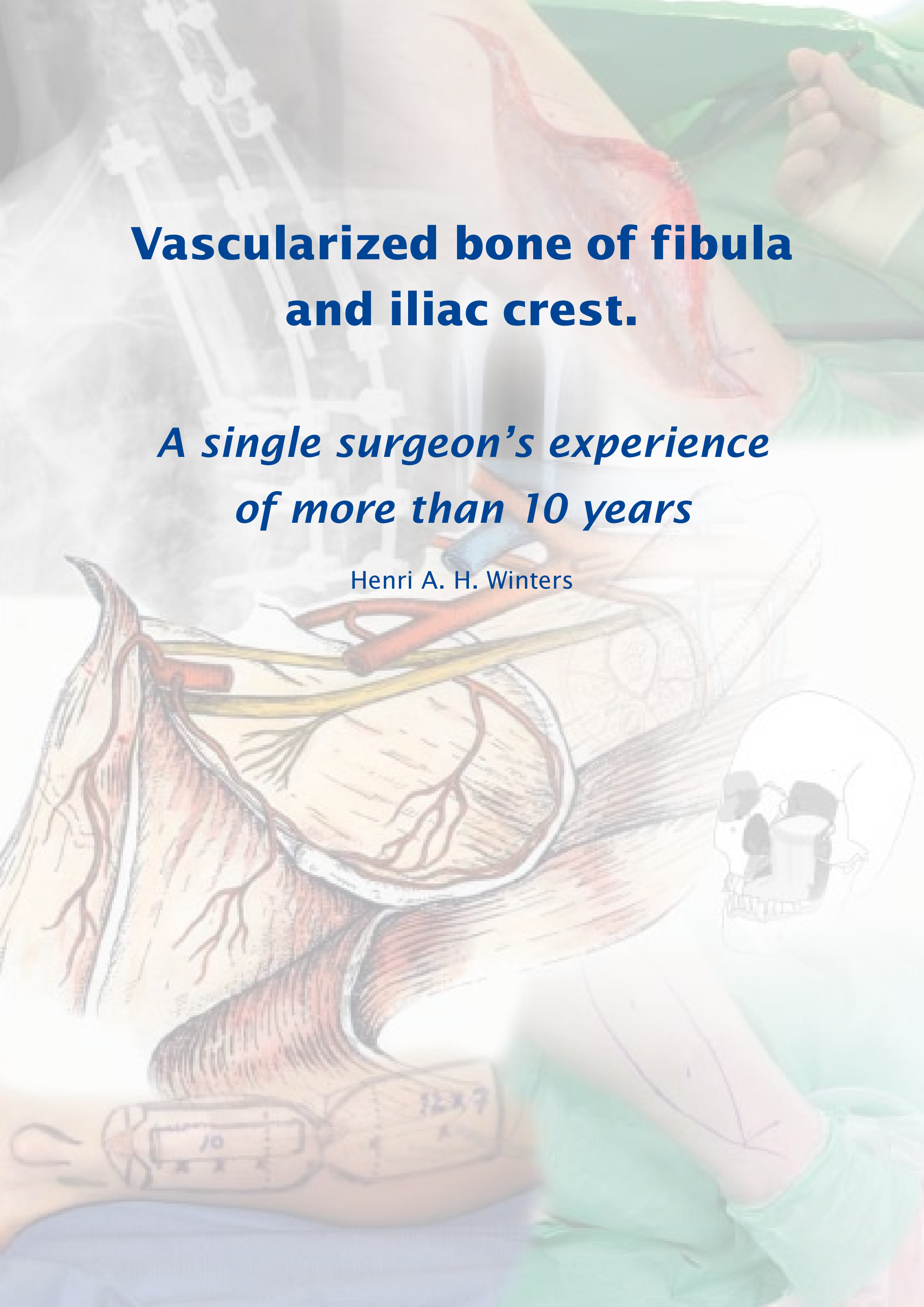
Winters, H.A.H.

2007

Vascularized bone of fibula and iliac crest.

A single surgeon's experience of more than 10 years

Henri A. H. Winters



VRIJE UNIVERSITEIT

Vascularized bone of fibula and iliac crest

A single surgeon's experience of more than 10 years

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. L.M. Bouter,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de faculteit der Geneeskunde
op vrijdag 28 september 2007 om 10.45 uur
in de aula van de universiteit,
De Boelelaan 1105

door

Henri Adolf Hubert Winters

geboren te Venlo

promotor: prof.dr. M.J.P.F. Ritt

De beoordelingscommissie van dit proefschrift was als volgt samengesteld:
Prof. Dr. Ch. R. Leemans
Prof. Dr. S Monstrey
Prof. Dr. J.L.N. Roodenburg
Prof. Dr. P. Scheltens
Prof. Dr. P.I.J.M. Wuisman

Dit proefschrift werd mede mogelijk gemaakt door financiële ondersteuning door de volgende sponsors:
Allergan bv
Biomet Nederland bv
Bloomedical Benelux nv
Carl Zeiss
Laprolan bv
Stichting Medisch Centrum Jan van Goyen
Stichting PCH-VU
Vrije Universiteit

ISBN: 9789086591343

Contents

Contents

1

Introduction

1 Introduction

Development of reconstructive microsurgery

There is a certain pattern in the development of reconstructive microsurgery. It started with the excitement about the sheer ability to do free vascularised tissue transfer. The main focus was on flap survival. This initiated a search for tissue that could be transferred using microsurgical techniques. A lot of flaps were ‘discovered’ based on the existing knowledge of vascular patterns. Functional outcome in the receptor area became an important issue, leading to insight in flap choice for different defects Algorithms for treatment of various defects were developed. Donorsite morbidity was the next aspect that needed attention. The changing, amending and refining of techniques to improve donorsite morbidity has consequences for the design and quality of the flaps, and this again may have consequences on the acceptorsite, so the process is never ending, being more of a spiral movement than a circular motion. Small changes in one of the aspects of a surgical technique will have consequences for the whole procedure and these –often minor- changes combined form the fine-tuning process. Flap location and design, functional outcome of the acceptor site and donorsite morbidity are linked and together they define the value of any reconstructive technique, as this process obviously is not limited to microsurgery. The development of perforator flaps is a good example of this spiral process.

The chapters of this thesis are no more than small bits and pieces of this spiral, and by no means this thesis pretends to be a finished entirety, as no publication in science will ever be.

Osseous free flaps in historical perspective

With the rise of microvascular tissue transfer within the field of reconstructive surgery in the late seventies and early eighties, new flaps were “discovered” in rapid succession. For obvious reasons, there was a need for free vascularised osseous flaps so most of the flaps we know and use today originate from this period. In the last two decades, free vascularised bone flaps have become common in reconstructive surgery. For many indications a vascularised bony reconstruction is preferred over an non vascularised bonegraft. The main advantages are: rapid consolidation, little or no resorbtion, potential to hypertrophy and resistance against infection. On the other hand, there are also disadvantages to be considered such as: elongated operating time, the risk of flap failure and donor site morbidity. In the Netherlands, the era of free vascularised bone transfers started with the publication of the thesis of Prof. Dr. Kurt Bos[1], a dutch pioneer study on transplantation of free vascularised autologons bone . Since that time, techniques have been modified and new indications have been found. This thesis is based on my personal experience with more than 200 free vascularised fibula and iliac crest flaps over a period of more than ten years. It consists mainly of peer reviewed papers published in scientific journals. As my personal experience begins 20 years after the first publication on the free vascularised fibula flap, it is obvious that this thesis is about details: The never ending process of refining surgical techniques, finding new clinical applications and revising old ones. As this thesis concerns about the two major workhorses in vascularised osseous flaps; the fibula and the iliac crest, it would be beyond the scope of this thesis to discuss all possible donorsites in depth. However, to put everything in historical and clinical perspective, I have included a small overview of the most important aspects of all major osseous flaps.

The fibula flap.

The first vascularised transfer of the fibula was reported by Taylor et.al. in 1975[(2)]. Chen and Yan were the first to include a fasciocutaneous skin paddle in the flap[(3)], but it was not until Hidalgo's paper in 1989 that this flap was used for reconstruction of the mandible and floor of mouth[(4)], a use for which this flap now is the first choice in most centres. The fibula is the strongest and longest bone available for transfer[(5)]. Up to 30 cm. of bone can be harvested in this flap. The fibula can easily be combined with a large skin paddle – sensate if desired[(6)] - of up to 30x15 cm. and can take multiple osteotomies without losing its vascularity. The fibula flap is covered extensively further in this thesis.

The iliac crest flap.

With the rise of mirovascular surgery, the iliac crest - well known as a non vascularized bonegraft - obviously was one of the first candidates to be converted into a free vascularised bone graft. Several pedicles for this flap have been described and used (see chapters 4 & 5), but in 1979 two independent reports by Taylor from Australia[(7)] and by Sanders and Mayou from Great Britain[(8)], proved the deep inferior circumflex iliac artery (DCIA) and vein to be the best vascular pedicle for transfer of the iliac crest flap. The possibility to include a skin paddle was also pointed out by Sanders and Mayou. In 1984, Ramasatry was the one to discover the possibility to include the internal oblique abdominal muscle in the flap, based on the ascending branch of the deep circumflex iliac vessels[(9)]. Urken started to use the internal oblique muscle for intra oral reconstruction in 1989 and popularised the use of this flap for oromandibular reconstruction[(10)]. The iliac crest flap has been used by the author of this thesis since 1992. first as the workhorse for most bony reconstructions, later, from 1995 on, the fibula flap became the flap of choice for most indications, the iliac crest becoming a good second with the exception of maxilla reconstruction, where it remains the flap of choice. The bony portion of the iliac crest flap can be up to 15x5 cm and can be taken mono-,bi- or tri-cortical.

It has a curved shape that can be useful for some indications. The thickness and quality of the dorsal part of the graft will be far less than that of the anterior part, and also the circulation will decrease moving dorsally, especially when osteotomies are performed.
Many further details of the iliac crest flap are discussed in various chapters of this thesis.

The radial forearm flap

This flap, also known as the 'chinese flap' was introduced in Chinese literature by Yang in 1981(11). In 1982 Chang published the first report in English(12). The technique was quickly adopted in the western world and became popular for intraoral reconstruction by the work of Soutar(13, 14). The flap has been the workhorse of fasciocutaneous flaps for many years, but has seen strong competition from various perforator flaps in recent years. Inclusion of a part of the radius has been described by Soutar, mostly for use in facial reconstruction. Only 1/3th. Of the circumference of the radius can be included over a length of 8-10 cm. The amount of bone is limited and it does not take osteotomies very well. Donorsite morbidity is substantial; pathologic fractures are seen in approximately 20% of cases and lead to functional impairment in most of the cases(15, 16, 17). Also the donorsite is considered unsightly. For these reasons, the osteocutaneous radial forearm flap has a limited use in reconstructive surgery.

The lateral arm flap

In 1982, Song and co-workers introduced the free lateral arm flap(18). This is a fasciocutaneous flap based on the posterior radial collateral artery and vein. It can be used as a sensate flap and/or as a carrier for a vascularised nerve graft. Although part of the humerus can be included in this flap(19), it has never become popular as an osteocutaneous flap. The donorsite can be closed primarily in many cases and is considered to be a lot less unsightly than the radial forearm flap donorsite. The main donorsite morbidity is radial nerve damage or compression.

The scapular and parascapular flaps.

Lucinda dos Santos was the first to perform a free scapular flap in a patient in 1980(20), but it was Teot and co workers who were the first to use it as an osteocutaneous flap(21). The circumflex scapular artery and vein are the base of the scapular and parascapular flaps, They originate from the subscapular vessels, which also provide the latissimus dorsi and serratus anterior muscles. This means that, if necessary, a whole complex of flaps, each on its own artery and vein, can be transferred on one vascular pedicle. The lateral border of the scapula, including the angulus, can be transferred with this flap. The bone is well vascularised and takes osteotomies well. The available bone length rates from

10 to 14 cm. and its strength is significantly less than that of the fibula[22, 23]. The most important restriction for the use of this reliable flap is its localisation. For most indications a two team approach is impossible and the patient has to be turned during the operation. Both operating time and the period of flap ischaemia are significantly elongated. Therefore this flap rarely is the first flap of choice. The major donorsite morbidity is impairment of shoulder function and scapular winging.

Vascularised rib grafts

Many varieties of this flap have been described[24, 25, 26]. Almost any muscle with an insertion on the ribs has been used in combination with rib as a bony component. The vascularisation of the bony part of these flaps has often been questioned. Furthermore, the quality of bone from the ribs is poor[1, 27]. For these reasons, rib is rarely used for the reconstruction of long bones or the mandible.

The value of this thesis in everyday clinical practice

Many developments take place at the same time, and it is virtually impossible to be fully informed about all of them. Therefore, in literature, there is a certain lag time in the inclusion of modifications in the description of certain techniques. Moreover, most authors describe only their modification in detail and leave it to the reader to combine the paper with its references and figure out the technical consequences of this combination. It is often taken for granted that everybody uses more or less the same technique, which is always referred to as 'the standard technique' or as 'being described in literature/the textbooks'. When looking for this generally accepted technique, it appears to be hard to find. Quite often only the first description ever is cited and most of the time descriptions are lacking a surprising lot of details. Maybe this is because authors think they are stating the obvious, maybe because publishers and reviewers are not happy with elaborate descriptions that go beyond the specific theme of the paper. This makes it difficult for the starting or less experienced surgeon to establish the state of the art in a certain technique at a certain point. To give this thesis a bit of clinical usefulness, I have included a detailed step by step description of my personal technique of raising free fibula and free iliac crest flaps, based on experience and literature, including every tip and trick I know. I sincerely hope these two chapters will help colleagues who are starting with free vascularised bone flaps to avoid pitfalls and to increase their confidence and success rate.

References

1. *Bos, K.E.Transplantatie van autoloog bot en revascularisatie door middel van microvaatanastomosen. Academisch proefschrift, Mondeel offsetdrukkerij Amsterdam, 1980.*

2. *Taylor GI, Miller G, Ham F. The free vascularised bone graft: A clinical extension of microvascular techniques. Plast Reconstr Surg 55:533, 1975.*

3. *Chen Z, Yan W. The study and clinical application of the osteocutaneous flap of fibula. Microsurgery 4:11, 1983.*

4. *Hidalgo DA. Fibula free flap: Anew method of mandible reconstruction. Plast Reconstr Surg 84:71, 1989.*

5. *Serra A, Paloma V, Messa F, Ballesteros A. The vascularised fibula in mandibular reconstruction. J Oral Maxillofac Surg 49:244, 1991.*

6. *Hayden R, O'Leary M. A neurosensory fibula flap: Anatomical description and clinical applications. Presented at the 94th annual meeting of the American Laryngological, Rhinological and Otological society meeting, Hawaï, May 8, 1991.*

7. *Taylor GI, Townsend P, Corlett R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. Plast Reconstr Surg 64:595, 1979.*

8. *Sanders R, Mayou B. A new vascularized bone graft transferred by microvascular anastomosis as a free flap. Br J Surg 66:787, 1979.*

9. *Ramasatry SS, Tucker JB, Swartz WM, Hurwitz DJ. The internal oblique muscle flap: an anatomic and clinical study. Plast Reconstr Surg 73:721, 1984.*

10. *Urken ML, Vickery C, Weinberg H, Buchbinder D, Biller H. The internal oblique-iliac crest osseo-myocutaneous microvascular free flap in head and neck reconstruction. J Reconstr Microsurg 5:203, 1989*

11. *Yang G, Chen B, Gao Y. Forearm free skin flap transplantation (Chinese). Natl Med J China61:139, 1981.*

12. *Chang TS, Wang W, Hsu CY. The free radial forearm flap – a report of 25 cases. Ann Acad Med Singapore 11:236, 1982.*

13. *Soutar DS, Scheker LR, Tanner NS, McGregor IA. The radial forearm flap: aversatile method for intra-oral reconstruction. Br J Plast Surg 36:1, 1983.*

14. *Soutar DS, McGregor IA. The radial forearm flap in intraoral reconstruction: the experience of 60 consecutive cases. Plast Reconstr Surg 78:1, 1986.*

15. *Bardsley AF, Soutar DS, Elliot D, Batchelor AG. Reducing morbidity in the radial forearm flap donor site. Plast Reconstr Surg 86:287, 1990.*

16. *Boorman JG, Brown JA, Sykes PJ. Morbidity in the forearm flap donor arm. Br J Plast Surg 40:207, 1987.*

17. *Swanson E, Boyd JB, Mulholland RS. The radial forearm flap: A biomechanical study of the osteotomized radius. Plast Reconstr Surg 85:267, 1990.*

18. *Song R, Song Y, Yu Y, Song Y. The upper arm free flap. Clin Plast Surg 9:27, 1982.*

19. *Katsaros J, Schusterman M, Beppu M, Banis J Jr, Ackland RD. The lateral upper arm flap: Anatomy and clinical applications. Ann Plast Surg 12:489, 1984.*

20. *Dos Santos LF. Retalho scapular: Um novo retalho livre microchirurgico. Bras Cir 70:133, 1980.*

21. *Teot L, Bosse JP, Moufarrege R, Papillon J, Beuregard G. The scapular crest pedicled bone graft. Int J Microsurg 3:257, 1981.*

22. *Thoma A, Archibald S, Payek I, Young JEM. The free medial scapular osteofasciocutaneous flap for head and neck reconstruction. Br J Plast Surg 44:477, 1991.*

23. *Swartz WM, Banis JC, Newton ED, Ramasatry SS Jones NF, Ackland R. The osteocutaneous scapula flap for mandibular and maxillary reconstruction. Plast Reconstr Surg 77:530, 1986*

24. *Ariyan S et. al. The anterior chest approach for obtaining free osteocutaneous rib grafts. Plast Reconstr Surg 62:676, 1978.*

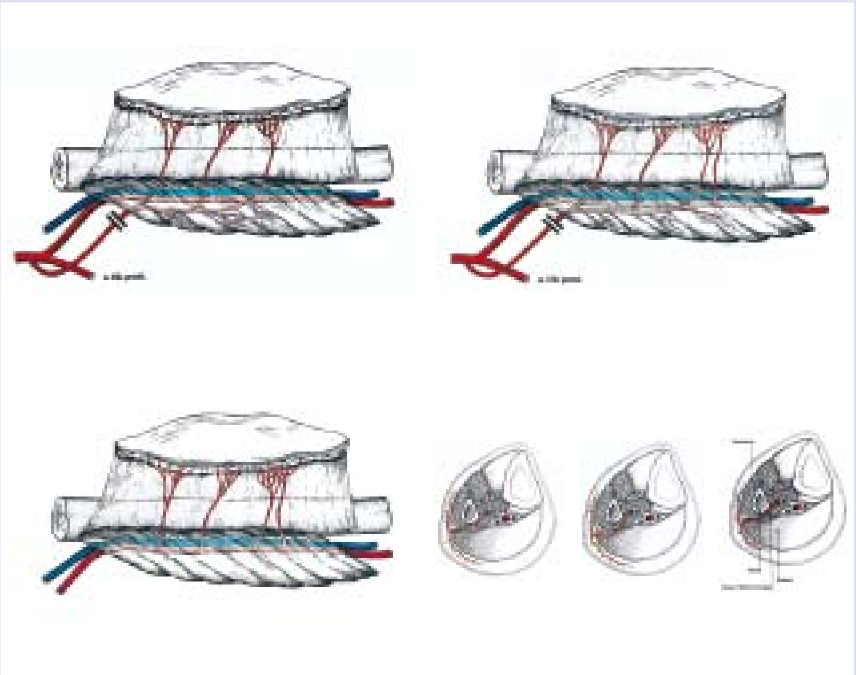
25. *McKee DM. Microvascular bone transplantation. Clin Plast Surg 5:283, 1978.*

26. *Harashina T et. al. Reconstruction of mandibular defects with revascularised rib free grafts. Plast Reconstr Surg 62:514, 1978.*

27. *Daniel RK. Mandibular reconstruction with free tissue transfers. Ann Plast Surg 1: 737, 1978.*

2

Reliability of the Proximal Skin Paddle of the Osteocutaneous Free Fibula Flap: A Prospective Clinical Study



2 Reliability of the Proximal Skin Paddle of the Osteocutaneous Free Fibula Flap: A Prospective Clinical Study

Winters, Henri A. H. M.D.; de Jongh, Ghita J. M.D., Ph.D.

Abstract

The vascularization of the skin paddle of 20 osteocutaneous fibula free flaps in 20 patients was studied. All skin paddles were designed over the proximal and middle third of the fibula. A parallel vascularization of the skin was found in 10 cases. In these cases, an axial (septo) musculocutaneous perforator was found to originate high in the peroneal artery or even in the popliteal artery. This branch runs parallel to the peroneal artery without any further connections with it. In 5 of these 10 cases, no other skin perforators were located within the boundaries of the skin paddle. Harvesting such a flap in the traditional way by blind inclusion of a muscle cuff results in ligation of the supplying vessel of the skin paddle and subsequent loss of the skin. In this series, this would have been the case in 5 of the 20 patients (25 percent). This might explain the bad reputation of the skin paddle of this flap. The high prevalence of the described vascular configuration in a proximally designed skin paddle, justifies à vue dissection of all musculocutaneous perforators up to their origin, unless one or more septocutaneous perforators are found within the boundaries of the flap.

Introduction

The osseous fibula free flap was introduced by Taylor et al. in 1975.[1] Chen and Yan modified the use of this flap by including a skin paddle based on the perforating cutaneous branches of the peroneal artery.[2]

The configuration of the skin perforators of the fibula flap is often presented as being perpendicular to the peroneal artery and more or less evenly distributed *(Fig. 1)*. Perforators can be septocutaneous, musculocutaneous, or septomusculocutaneous *(Fig. 2)*. To preserve these perforators, inclusion of a muscle cuff has been advocated.[2,3] Dissection of the skin perforators out of the muscle has also been suggested.[4] Allegedly, distally located skin paddles are more reliable than proximally located skin paddles.[5] Although this osteocutaneous flap is widely used for reconstruction of oromandibular defects, there is an ongoing discussion regarding the exact vascularization and reliability of the skin paddle.
It seems that some of the views given in the literature are contradictory. Moreover, our intraoperative observations were not always in accordance with the literature. Therefore, we performed a prospective study on the configuration

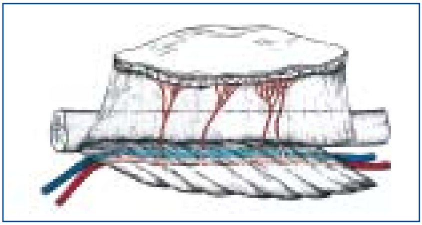


Fig. 1. A mean of five septocutaneous, musculocutaneous, or septomusculocutaneous perforators has been described to arise directly from the peroneal artery.

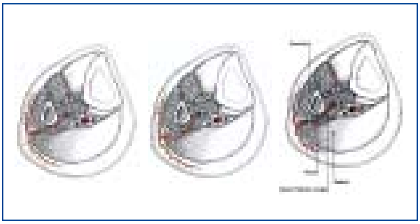


Fig. 2. (Left) Septocutaneous perforator. (Center) Musculocutaneous perforator. (Right) Septomusculocutaneous perforator.

of skin perforators in osteocutaneous fibula free flaps with proximally located skin paddles.

Materials and Methods

From February of 1995 to November of 1996, 20 osteocutaneous fibula free flaps in 20 patients were evaluated in a prospective clinical study. Nineteen patients underwent reconstruction of oromandibular defects, whereas the flap was used for phalloplasty in one transsexual patient. In all patients, the skin paddle was designed over the middle and proximal third of the lower leg and ranged from 5 × 12 cm to 9 × 22 cm. All flaps were harvested without tourniquet to diminish edema and vascular spasm. The skin paddle was incised and harvested subfascially up to the septum between the soleus and peroneus muscles. The skin perforators were then identified. All septocutaneous, septomusculocutaneous, or musculocutaneous skin perforators were dissected up to their origin. Whenever embedded in the soleus or flexor hallucis longus muscle, the perforators were dissected out of the muscle. All muscle branches were clipped or ligated. The soleus and flexor hallucis longus muscles were dissected of the fibula, and the proximal part of the pedicle was reached. Subsequently, the peroneal muscle was dissected of the fibula, revealing the peroneal nerve. The interosseous membrane was divided and proximal and distal osteotomies were performed. The vascular pedicle was separated from the posterior tibial muscle and dissected up to the level of the posterior tibial artery. The configuration of all skin perforators in each of the 20 flaps was studied and scored.

Results

One flap was completely lost due to infection of the neck after an uneventful course up to day 10. Other than in that case, no complete or partial necrosis of the skin paddle was observed.

Of the 20 skin paddles of this series, 7 were found to have solely one or more septal perforators. Six had septomusculocutaneous perforators, whereas the

remaining seven only had musculocutaneous perforators. In 10 of the latter 13 flaps, one or more of the septomusculocutaneous or musculocutaneous perforators had no direct connection to the peroneal vessels. Rather, the skin perforators converged with muscle branches to form separate musculocutaneous vessels running completely embedded in muscle and parallel to the peroneal artery. These originated high in the peroneal artery or even in the popliteal artery *(Fig. 3)*. In 5 of the 10 cases with such a parallel musculocutaneous branch, no further perforators were found and the skin paddle was depending solely on the parallel musculocutaneous branch for its vascularization. In three of these five cases, the musculocutaneous branch originated in the popliteal artery, necessitating a separate anastomosis. In the remaining five cases, more distally located perforators were found within the boundaries of the skin paddle *(Fig. 4)*. These distal perforators ran directly from the peroneal artery through the flexor hallucis muscle and septum to the skin.
In all 10 cases in which parallel musculocutaneous vessels were present, these vessels were clamped intraoperatively to test whether the skin paddle was sufficiently vascularized through the septum alone. In the five cases in which no septal perforators were found, the skin turned ischemic and showed no bleeding at the edges. After removal of the vessel clamp, the skin paddle immediately turned pink and bleeding of the flap recurred.

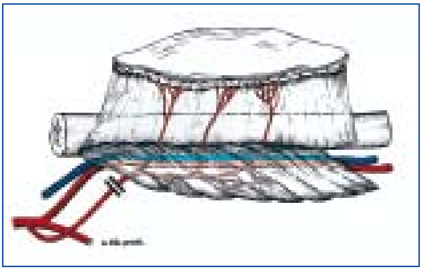


Fig. 3. In this sagittal section, the skin perforators have no direct relation with the peroneal vessels, but find their origin in a musculocutaneous branch. This branch runs parallel to the peroneal artery, completely embedded in the soleus muscle, giving off muscle branches and skin perforators. It originates high in the peroneal artery or even in the popliteal artery. In these cases, harvesting the flap in the traditional way results in loss of the skin paddle because of ligation of the supplying vessel of the skin paddle (double bars).

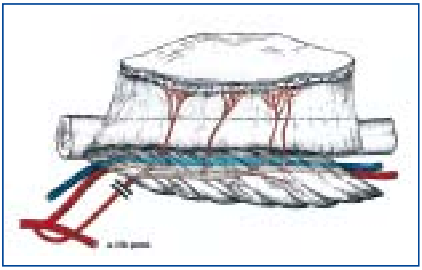


Fig. 4. Parallel musculocutaneous branch in combination with distally located direct skin perforator. The skin paddle survives after ligation of the parallel branch (double bars).

Discussion

In the first article on the osteocutaneous fibula free flap, Chen and Yan advised incorporating a cuff of soleus muscle, flexor hallucis longus muscle, and posterior tibialis muscle into the flap to ensure that the cutaneous branches were kept intact.(2) Still, the skin paddle of this flap was considered quite unreliable, and(6,7) over the years, several modifications to the surgical technique have been suggested to improve its reliability. In 1986, Wei et al. proposed to simplify the technique and save time by harvesting the flap on the posterior crural septum alone, without inclusion of a muscular cuff.(4) However, when no septocutaneous vessels appeared to traverse the septum (13.3 percent in their study), these authors have suggested an intramuscular dissection of the musculocutaneous branches.(4) Hidalgo proposed in 1989 that the septocutaneous supply is generally not adequate to support a skin island for intraoral soft-tissue replacement.(6) But he renounced his pessimistic view after observing 90 percent skin island survival in his patients.(8) After an elaborate study on the anatomy of the vascularization of the skin paddle, Schusterman et al. concluded, in concordance with Chen and Yan, that a muscle cuff should be included to enhance the reliability of the island.(3) To maximize the amount of skin perforators incorporated in the flap, Anthony et al. suggested harvesting a long segment of fibula and an equally long segment of overlying skin. Rather than resect the skin not needed for surface reconstruction, they advocated to deepithelialize it, thus preserving the maximum amount of perforators.(9)

The discussion on the reliability of the skin paddle seems to be correlated to the difference between proximal and distal skin vascularization. Most studies agree on the localization of distal skin perforators.(3,5,10) At that level, the perforators are predominantly of the septocutaneous or musculoseptocutaneous type and run perpendicular to the peroneal artery. Therefore, the distal skin paddle design of the fibula osteocutaneous flap is favored and good results are obtained.(5,10,11) Recently Jones et al. even suggested harvesting the flap solely on the septum, provided the flap is situated at the junction of the distal and middle third of the lower leg.(5) They ligated all musculocutaneous branches, even when no septal branches were visible. No failure was observed in this study.

However, a proximal skin paddle has advantages. Unlike the distal design, a proximal skin paddle provides better suitability for sensitization and it allows primary closure of the defect or the possibility of raising a large skin island.(12,13) The proximal perforators are mostly of the musculocutaneous type, but their anatomy has not been described in detail.(10,14) In 50 percent of the cases in our series, these musculocutaneous perforators had no direct relation with the peroneal vessels, but found their origin in a parallel musculocutaneous branch that originated high in the peroneal artery or even in the popliteal artery. In cases in which all skin perforators arise from this branch (25 percent in our series), the skin paddle has no direct connection with the peroneal artery (Fig. 3). Harvesting the flap in the traditional way would then result in ligation of the supplying vessel of the skin, even in cases in which a muscle cuff is included.

Often one or more distal septocutaneous or musculoseptocutaneous perforators exist *(Fig. 4)*. If these are within the boundaries of the flap, the proximal musculocutaneous branch can be ligated without adverse effects. However, if no septal perforators are found, all skin perforators should be carefully dissected out of the soleus muscle up to their origin. All muscle branches should be clipped or ligated. It may be necessary to perform a separate anastomosis of this branch (three cases in our study). Unlike Jones, we found the skin paddle to become ischemic when based only on a septum devoid of perforators. Weber et al. describe two cases of salvage of the skin paddle of an osteocutaneous fibula flap by means of a separate anastomosis.15 Their cases are similar to the three in our study and confirm our findings.

Conclusions

The vascularization of a proximal skin paddle of the osteocutaneous fibula free flap often depends on musculocutaneous perforators that find their origin high in the peroneal artery or even in the popliteal artery. If the septum is devoid of perforators, all musculocutaneous perforators should be dissected up to their origin. Separate anastomosis of vascular supply to the skin may be necessary.

References

1. *Taylor, G. I., Miller, G. D. H., and Ham, F. J. The free vascularized bone graft: A clinical extension of microvascular techniques. Plast. Reconstr. Surg. 55: 533, 1975. Ovid Full Text ExternalResolverBasic Bibliographic Links*

2. *Chen, Z. W., and Yan, W. The study and clinical application of the osteocutaneous flap of fibula. Microsurgery 4: 11, 1983. ExternalResolverBasic Bibliographic Links*

3. *Schusterman, M. A., Reece, G. P., Miller, M. J., and Harris, S. The osteocutaneous free fibula flap: Is the skin paddle reliable? Plast. Reconstr. Surg. 90: 787, 1992.*

4. *Wei, F. C., Chen, H. C., Chuang, C. C., and Noordhoff, M. S. Fibular osteosepto-cutaneous flap: Anatomic study and clinical application. Plast. Reconstr. Surg. 78: 191, 1986.*

5. *Jones, N. F., Monstrey, S., and Gambier, B. A. Reliability of the fibular osteocutaneous flap for mandibular reconstruction: Anatomical and surgical confirmation. Plast. Reconstr. Surg. 97: 707, 1996. Ovid Full Text ExternalResolverBasic Bibliographic Links*

6. *Hidalgo, D. A. Fibula free flap: A new method of mandible reconstruction. Plast. Reconstr. Surg. 84: 71, 1989. Ovid Full Text ExternalResolverBasic Bibliographic Links*

7. *Van Twisk, R., Pavlov, P. W., and Sonneveld, J. Reconstruction of bone and soft tissue defects with free fibula transfer. Ann. Plast. Surg. 21: 555, 1988. Ovid Full Text ExternalResolverBasic Bibliographic Links*

8. *Hidalgo, D. A. Aesthetic improvements in free-flap mandible reconstruction. Plast. Reconstr. Surg. 88: 574, 1991. Ovid Full Text ExternalResolverBasic Bibliographic Links*

9. *Anthony, J. P., Ritter, E. F., Young, D. M., and Singer, M. I. Enhancing fibula free flap skin island reliability and versatility for mandibular reconstruction. Ann. Plast. Surg. 31: 106, 1993. Ovid Full Text ExternalResolverBasic Bibliographic Links*

10. Wolff, K. D., Ervens, J., Herzog, K., and Hoffmeister, B. Experience with the osteocutaneous fibula flap: An analysis of 24 consecutive reconstructions of composite mandibular defects. J. Craniomaxillofac. Surg. 24: 330, 1996. ExternalResolverBasic Bibliographic Links

11. Yim, K. K., and Wei, F. C. Fibula osteoseptocutaneous flap for mandible reconstruction. Microsurgery 15: 245, 1994.

12. Wei, F. C., Chuang, S. S., and Yim, K. K. The sensate fibula osteoseptocutaneous flap: A preliminary report. Br. J. Plast. Surg. 47: 544, 1994.

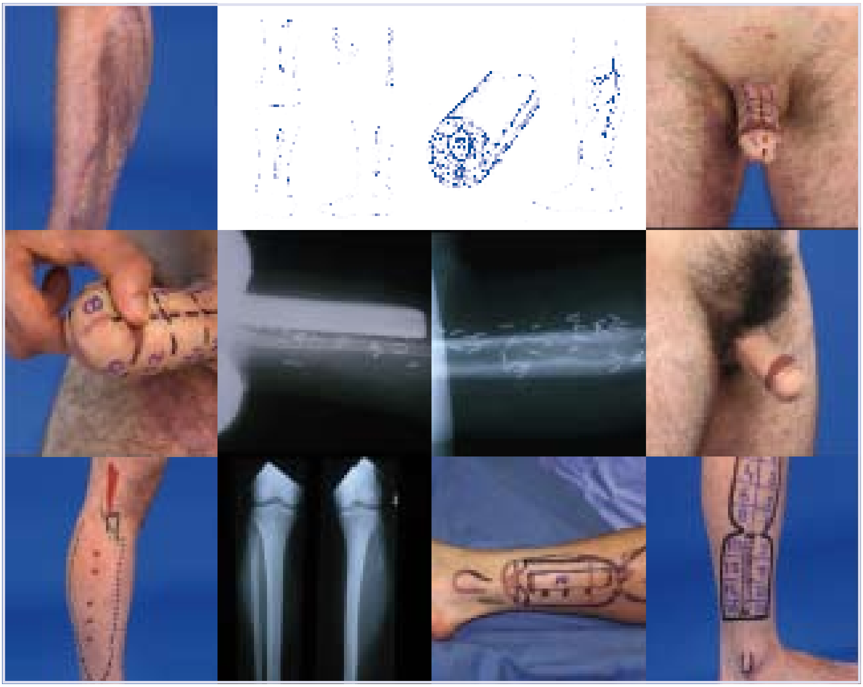
13. Hage, J. J., Winters, H. A. H., and van Lieshout, J. Fibula free flap phalloplasty: Modifications and recommendations. Microsurgery 17: 358, 1996. ExternalResolverBasic Bibliographic Links

14. Beppu, M., Hanel, D. P., Johnston, G. H., Carmo, J. M., and Tsai, T. M. The osteocutaneous fibula flap: An anatomical study. J. Reconstr. Microsurg. 8: 215, 1992. ExternalResolverBasic Bibliographic Links

15. Weber, R. A., and Pederson, W. C. Skin paddle salvage in the fibula osteocutaneous free flap with secondary skin paddle vascular anastomosis. J. Reconstr. Microsurg. 11: 242, 1995. ExternalResolverBasic

3

Fibula free flap phalloplasty: modifications And recommendations



3 Fibula free flap phalloplasty: modifications And recommendations

J. Joris hage, m.D., Ph.D.,* Henri a.H. Winters, m.D., And jesse van lieshout

* *Correspondence to: J.J. Hage, Department of Plastic and Reconstructive Surgery, Academisch Ziekenhuis Vrije Universiteit, P.O. Box 7057, NL-1007 MB Amsterdam, The Netherlands.*

Abstract

Radial forearm flap phalloplasty should be regarded as the gold standard. The large forearm donor site scar, however, has led to the search for other donor areas. We present our modifications and recommendations for addressing the ideal goals of phalloplasty better when applying the fibula free flap. We recommend preconstruction and secondary anastomosis of the neo-urethra. Preoperative infiltration of the cutaneous nerve is recommended for planning of the sensate flap. The osseous part of the flap should be long enough to be fixed to the tunica albuginea. We recommend a longitudinal, rather than a transverse, design for the flap. For aesthetic reasons, the flap should include two triangular tongues. Even so, secondary surgery will be needed. The patient may be left with functional loss in the donor region. A case report illustrates all of these points. We conclude that the sensate fibula free flap has a place in phalloplasty in case the patient refuses a forearm scar.

Introduction

Ideally, in phalloplasty the surgeon should aim for:

1. A one-stage procedure that can be predictably reproduced
2. Creation of a competent neo-urethra to allow for voiding while standing
3. Return of both tactile and erogenous sensibility
4. Enough bulk to tolerate the insertion of a prosthetic stiffener
5. A result that is aesthetically acceptable to the patient[1]

Use of a tube-in-a-tube rolled radial forearm free flap will allow for a maximum of these ideal goals to be addressed and should be regarded the gold standard.[2,3] However, as minimal scarring or disfigurement and no functional loss in the donor area are further requirements for any ideal procedure, the large scar in the donor region should be mentioned as the major drawback of the radial forearm technique. This was one of the reasons that Sadove et al.[4,5] began using fibula osteocutaneous free flaps for phalloplasty, the other two reasons being the intrinsic rigidity of this flap and the superior length of its vascular pedicle. In this article we present modifications and recommendations in fibula free flap phalloplasty to address further the ideal goals of phalloplasty.

One-stage procedure

When applying microsurgical techniques, the actual phalloplasty may be completed in one stage. To simplify and to ensure a safe technique for this procedure, we have suggested using an arterialised loop of the greater saphenous vein anastomosed end to side to the femoral artery.(6) This allows for one competent venous and one arterial anastomosis to be made between flap and recipient vessels. Even so, using the fibula flap will not meet all of the abovementioned requirements in one procedure.(7) This is mainly due to the wish to create a competent pars pendulans urethrae that will enable the patient to void in a male fashion.(8,9)

Urethroplasty

Sadove et al.(4,5) reported being able to tube the fibula flaps the Chinese way, ensuring the tube-in-a-tube urethroplasty. This, they recognised, leads to excessive tension of the neo-phallus upon closure during surgery with subsequent urethral fistulation, as well as the need to reduce the excessive penile girth afterward by liposuction. For this reason, Sadove et al.(5) changed their technique to wrapping the fibula flap around both the fibular bone and a fullthickness skin graft tubed around a catheter. Because in one of the two patients thus treated this resulted in urethral stenosis, they suggested that a full-thickness graft be performed on the leg as an additional operation to prefabricate the flap and ensure an adequate urethra prior to flap transfer.(5,9) This necessitates an extra stage in phalloplasty. For such a urethral prefabrication, it is not necessary to incise the leg over the entire length of the neo-urethra. Rather, the hairless full-thickness skin graft stented on a no. 30 catheter may be inserted in a subcutaneous tunnel extending from one meatal incision to the other.(10) Both these incisions are made in a triangular fashion, and the resulting triangular skin flaps are folded inward into the subcutaneous tunnel to prevent stenosis of the otherwise circular meatal scar *(Fig. 1)*.(11) However, in our opinion, connection of such a prefabricated pars pendulans urethrae to the fixed part should be done as a separate procedure subsequent to the actual phalloplasty and after all scars have become soft and pliable.(9) This makes this technique inferior to the use of tube-in-atube rolled free flap techniques, in which we feel confident in anastomosing the pars pendulans and pars fixa immediately, leaving a third stage superfluous. Still, prefabrication of the pars pendulans urethrae will reduce the width of the flap needed for phalloplasty and hence will reduce the donor area defect.

Sensibility

In 1993, one of us suggested reinnervating the cutaneous part of the free fibula osteocutaneous flap by use of the lateral sural cutaneous nerve (LSCN).(12)

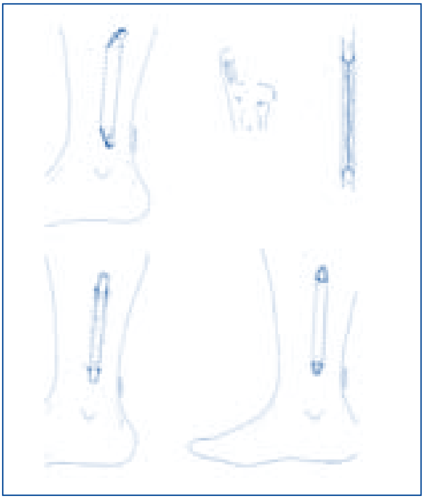


Figure 1. For urethral prefabrication, a subcutaneous tunnel is made in between two triangular incisions. The resulting triangular skin flaps are folded inward into the subcutaneous tunnel to prevent stenosis of the otherwise circular meatal scar (upper left). A hairless full-thickness skin graft harvested from the inner aspect of the upper arm is stented on a no. 30 catheter (upper right) and inserted in this tunnel (lower left). This results in a skin-lined subcutaneous tunnel free of fistulas to be used as a urethra (lower right).

In reply, Dr. Sadove[13] indicated that this had been undertaken in his patients while (like us) he was unaware of any report of a previous attempt to restore sensibility to this flap. Subsequently, Woerdeman et al.[14,15] presented the results of a micro-anatomical study of the distribution of the LSCN. From a series of 33 cadaveric lower limbs they concluded that in three-fourths of cases the LSCN innervated only the part of skin dorsal to the posterolateral intermuscular septum. A ventral branch of the nerve could be observed in one-fourth of the 33 limbs. In only half of their series was the LCSN found within a 3 cm margin dorsal to the septum. When allowing for a 4 cm dorsal margin, however, the LCSN could be included in four-fifths of the flaps. Woerdeman et al.[14,15] concluded that the fibula free flap should be designed more dorsally, rather than centrally over the posterolateral intermuscular septum. To allow for clinical and individualised application of this information, we recommend preoperative infiltration of the nerve with some local anaesthetic where it crosses the lateral boundary of the popliteal fossa over the tendon of the biceps femoris muscle or its insertion into the head of the fibula.[16] The resulting numbness on the lateral aspect of the lower leg corresponds to the area innervated by the nerve *(Fig. 2)*. Rather than determining the innervated area intraoperatively by neurosome mapping according to Urken's group,[17] this will allow for preoperative planning of a sensate cutaneous part of the flap, provided, of course, that this part includes the perforating cutaneous branches of the peroneal artery. Moreover, even though the peroneal communicating branch of the common peroneal nerve that joins the medial sural cutaneous nerve to form the sural nerve may be a branch of the LSCN, the area innervated by the LSCN is generally accepted to be the proximal two-thirds of the lateral aspect of the lower leg *(Fig. 2)*.[18] Therefore, a more proximal design of the flap is favourable. This was confirmed in one of

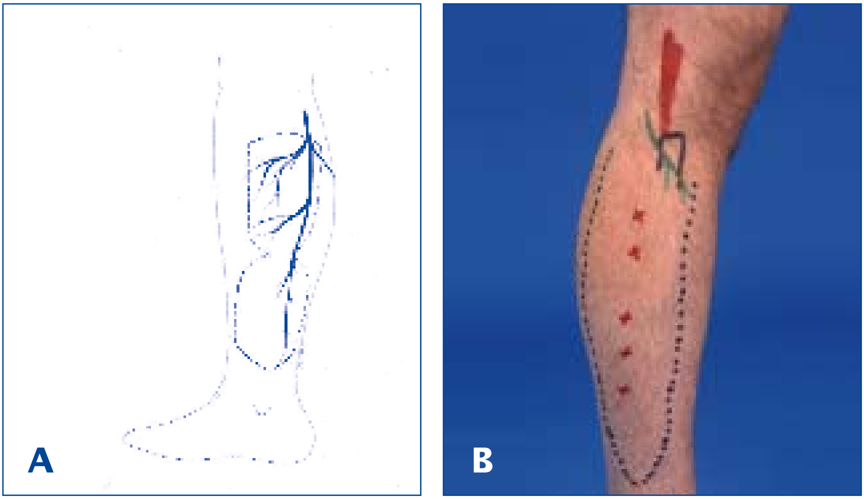
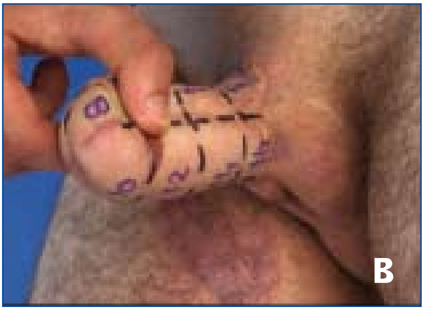


Figure 2. Even though the peroneal communicating branch of the common peroneal nerve that joins the medial sural cutaneous nerve to form the sural nerve may branch from the LSCN, the area innervated by the LSCN is generally accepted to be the proximal twothirds of the lateral aspect of the lower leg (A). To allow for a clinical and individualised application of this information, we recommend to preoperative infiltration of the nerve with some local anaesthetic where it crosses the lateral boundary of the popliteal fossa over the tendon of the biceps femoris muscle or its insertion to the head of the fibula. The resulting numbness on the lateral aspect of the lower leg (within the dotted line) corresponds to the area innervated by the nerve (B).

our patients in whom we used Semmes-Weinstein monofilaments to compare the sensibility of the neo-phallus with the sensibility of the area corresponding to the donor area of the contralateral leg *(Fig. 3)*.[19] It was found that following coaption of the LSCN, sensibility had recurred mainly in the dorsal aspect of the neo-phallus, corresponding to the proximal part of the fibula flap. This part, however, showed full recovery of the original sensibility *(Table 1)*. The extreme distal design of the flap, as suggested by Sadove et al.[4,5] to allow the donor site scar to be readily covered with a sock, does not appear to be in keeping with superior reinnervation. To provide the neo-phallus with tactile sensibility, the LCSN may be coapted to one of the two dorsal penile or clitoral nerves.[20] This should not be expected to result in erogenous phallic sensibility even though some of our patients claim this to be the case.[21] For this reason, the contralateral clitoral dorsal nerve and the clitoris should be left unharmed in female-to-male transsexuals to preserve erogenous sensibility.[3] Whenever two nerves are available in any flap, one of the ilioinguinal nerves may be recruited to be coapted to the second nerve of the transplant in this particular group of patients.



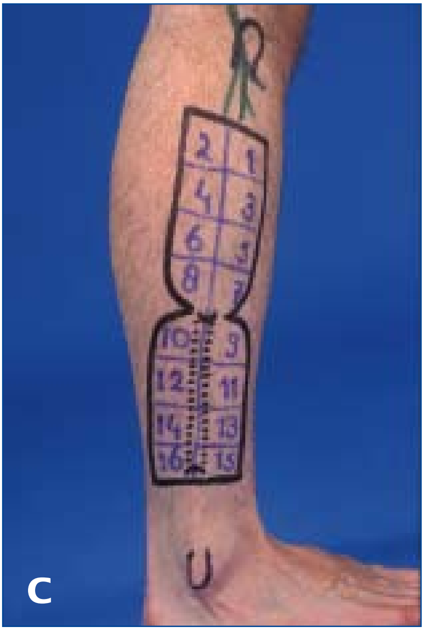


Figure 3. That a more proximal design of flap is favourable could be confirmed in one of our patients in whom we used the Semmes-Weinstein monofilament pressure aesthesiometer to compare recurrent sensibility of the neo-phallus (A and B) with the sensibility of the area corresponding to the donor area at the contralateral leg (C). Near normal sensibility recurred only in the dorsal aspect of the neo-phallus, corresponding to the proximal part of the fibula flap (see also Table 1).

Table 1. *Results of the Semmes-Weinstein Monofilament Pressure Aesthesiometer Comparing the Sensibility of the Neo-phallus With the Sensibility of the Area Corresponding to the Donor Area on the Contralateral Leg*[a]

Site no.	Leg	Phallus
1	3.61	3.22
2	3.61	3.61
3	3.61	3.61
4	4.17	3.84
5	3.61	3.61
6	3.61	4.17
7	3.61	3.84
8	3.61	3.22
9	3.22	—
10	3.22	4.17
11	3.22	—
12	3.22	4.17
13	3.61	—
14	3.61	4.56
15	3.22	—
16	3.22	3.84

[a] *Near normal sensibility recurred only in the dorsal aspect of the neo-phallus, corresponding to the proximal part of the fibula flap. See Figure 3.*

Rigidity

In phalloplasty, obtaining sufficient rigidity to allow for sexual penetration is difficult. Results of the combination in one phallus of a neo-urethra and a stiffener have been even more disappointing.[22] The basic limiting factor is that there is no good substitute for the unique erectile tissue of the penis to be used in the (re)construction.[20,23,24] For Sadove et al.,[5] the canine os penis has been the inspiration to use the osteocutaneous fibula flap, and they regard its intrinsic rigidity as one of the advantages of this flap. Even so, resorption, curving and fracture of autologous bone transplants have been reported, and the constantly rigid phallus may serve as a source of embarrassment to the patient.[22]
Whilst designing and raising the flap, the surgeon has to bear in mind that the fibula bone transplant has to be fixed to the short (clitoral) or shortened (penile) corpora cavernosa, or even to the pubic symphysis. The level of fixation to any of these structures is likely to be deeper than that of the cutaneous suture line between the phallic and the pubic skin. Hence, to prevent the glans of the neo-phallus from becoming floppy, we recommend that the osseous part of the flap be designed approximately 2 cm longer than its cutaneous part *(Fig. 4A)*. The condition of this fully vascularized osseous flap was found to be favourable after up to 1 year of follow-up *(Fig. 4B)*. We are confident of its longterm condition provided no fracture occurs. Rather than fixing the fibular bone to the pubic symphysis, we suggest fixing it to the corporal tunica albuginea only.[5,25] This will allow for proper and functional transmission of the pistoning movement to the sexually sensate corpora during intercourse and will also allow the rigid phallus to have an unrestricted range of motion.
The intrinsic rigidity of the neo-phallus, which is expected to burden the patient with a constant source of embarrassment, can then be hidden by folding the phallus sideways.

Phallic cosmesis

To accomplish an aesthetically acceptable result the phallus should be of normal dimensions. For this, secondary surgery is needed to slim down the fibula flap neo-phallus even when full-thickness skin grafts are used for urethral prefabrication. Furthermore, aesthetic considerations imply the construction of a glans-like tip. The design of the flap should allow for two triangularly shaped parts to be joined to model a conic glans.[2,3] Furthermore, the coronal ridge and sulcus may be imitated by applying a circumferentially dissected skin flap to be sutured to its own base at the distal margin of the donor area to form a ridge in combination with a skin graft to the donor site in order, which would prevent flattening of the coronal ridge *(Fig. 5)*.[20,26] We do not feel confident to apply this technique primarily when further surgery to slim down the neo-phallus is to be expected.

Donor area cosmesis

The main advantage of the use of a fibula flap over the gold standard radial forearm flap phalloplasty lies in the less conspicuous donor site scar. Even when the extreme distal design of the flap suggested by Sadove et al.[5] is not applied, the donor scar will be easily covered by the trousers. To improve the relatively inconspicuous nature of the scar further, we recommend that the dorsal and ventral parts of the neo-phallus be designed in longitudinal continuity, rather than next to each other *(Fig. 6)*. This way, the extent of deficit of subcutaneous tissue will correspond to the extent of the fasciotomy necessary to raise the flap, hence bulging of the underlying muscles will make up for the loss of subcutaneous bulk *(Fig. 7)*. Pretransfer expansion or postoperative correction of the donor scar may still be indicated, the more so when an extended period of ischemia to raise the flap will result in severe oedema of the lower leg.

Donor area function

That the anterior aspect of the longitudinally designed flap will not reach the anterior tibial crest is a further ad. vantage of the longitudinal design over the wide transverse design. The shin will be unharmed and optimally protected by its native cover. Apart from this, the donor area morbidity to be expected is well documented.[27,28] We left a minimum of 8 cm of the distal part of the fibula, ensuring ankle stability *(Fig. 8)*. Proximally, except for its upper 6 cm, the full length of fibula was harvested along with the flap to facilitate raising the flap and its pedicle as well as to enhance the rate of skin island viability thought to be due to the inclusion of more of the underlying fasciocutaneous perforators supplying the skin. This may still leave the patient with some functional loss in the donor region, as is illustrated in the following case report.

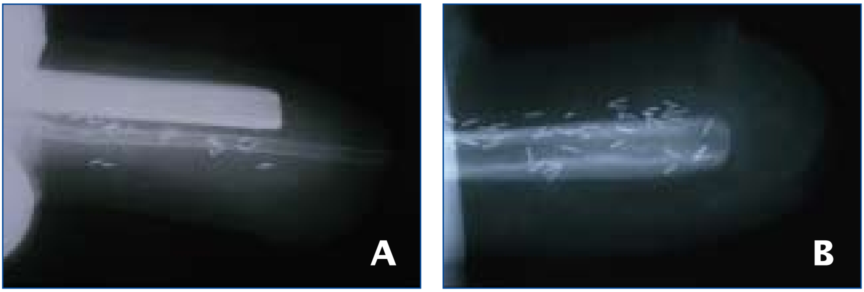
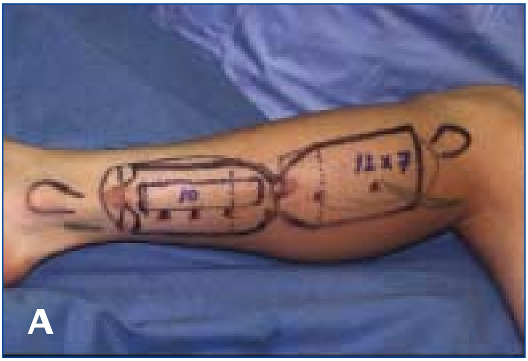


Figure 4. Use of a fibula osteocutaneous flap allows for combination of a prefabricated urethra and a stiffener within one flap (A). The osseous part of the fibula flap should be approximately 2 cm longer than its cutaneous part. In this case this was not done, resulting in a floppy glans of the neo-phallus. The condition of the fully vascularised osseous part of the flap was found to be favourable after tip to 1 year of follow-tip (B).

Figure 5. Result of secondary surgery that was needed to slim down the fibula flap neo-phallus and to imitate a coronal ridge and sulcus in the reported case.

Case report

After obtaining the general consent of the Amsterdam Gender Team, a 21-year-old female-to-male transsexual requested fibula free flap phalloplasty to prevent scarring of the forearm. The pars pendulans urethrae was prefabricated, and the actual phalloplasty was performed 6 months later, applying the longitudinal design of the fibula osteocutaneous free flap. The urethro-urethral anastomosis was done simultaneously. After 6 months, the phallus was slimmed down and the glans was sculptured using skin of the minor labia remnants to accentuate the coronal sulcus. As a result of recurrence of stenosis of the urethro-urethral anastomosis despite manual dilation three times daily, glansplasty was combined with longitudinal urethrotomy and insertion of a subcutaneously pedicled skin flap. Stenosis recurred, and 1 year post-phalloplasty, urethrotomy and flap surgery was repeated. Since the patient no longer made use of the clitoris for direct sexual stimulation, he asked for it to be buried in adjacent skin creases. The donor scar was also corrected during this latter procedure. So far, follow-up has been over 12 months. Apart from the urethral stenosis, healing of the phallus and the donor area have been uneventful. Tactile sensibility as tested using Semmes-Weinstein monofilaments is present at all of the dorsal aspect and some of the ventral aspect of the phallus. The patient also claims that some erogenous sensibility is present at the dorsal aspect. He masturbates through indirect stimulation of the clitoris by the bony segment in the phallus. He has not tried sexual intercourse as yet. The cosmesis of the phallus is considered excellent by the patient. He shaves the hairs of the phallus once daily. The lower leg donor scar is acceptable to him. To soften this scar, the patient applies a silicone dressing at night. The scar is easily covered by trousers, but not entirely by a sock. Motor function of the leg was restored 4 weeks after surgery. The patient still experiences some ankle instability when standing on one leg, while medium distance running leads to discomfort in the donor area and at the medial aspect of the distal tibia. The latter is similar to the tibial fasciitis he experienced prior to phalloplasty. However, this occurs after 2, instead of 12 km. On radiographs, the tibia and the ankle configuration show no deformities.



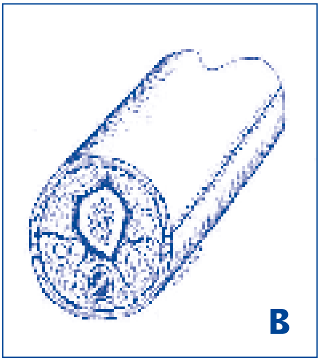


Figure 6. A longitudinal, rather than a transverse design of the flap was used to improve further the relatively inconspicuous nature of the donor site scar. This has the further advantage that the shin will be unharmed (A). The distal half of this flap containing the urethra is folded back under its proximal part to include the bone. This results in two lateral scars in the neo-phallus (B).

Figure 7. Bulging of the underlying muscles after raising the longitudinally designed flap will make up for the loss of subcutaneous bulk. Still, secondary correction of the donor scar was performed 1 year after phalloplasty in this case.

Figure 8. Symmetrical ankle configuration and stability was ensured by leaving a minimum of 8 cm of the distal part of the fibula. Proximally, the upper 6 cm of fibula was also left in situ.

Epilogue

For the (re)construction of the phallus a plethora of techniques has been suggested and used. The desires of the patient and his body habitus are included in the selection of surgical technique, as are the surgeon's preference and experience. Even though the ideal requirements have not been met by any technique so far, free flap phalloplasty leads to superior results, both functionally and cosmetically. It allows for reinnervation of the neo-phallus, in which lies the justification of donor site disfigurement, for these techniques will result in extensive scarring of the donor area unless labourious techniques such as tissue expansion are used. Still, the donor area may be chosen in such a way as to prevent conspicuous scarring. For these reasons, the sensate fibula osteocutaneous free flap has a place in phalloplasty in case the advantages of a free flap are sought when the patient refuses a forearm scar.

References

1. *Gilbert DA, Horton CE, Terzis JK, Devine CJ, Jr., Winslow BH, Devine PC: New concepts in phallic reconstruction. Annals of Plastic Surgery 18: 128–136, 1987.*

2. *Chang TS, Hwang WY: Forearm flap in one-stage reconstruction of the penis. Plastic and Reconstructive Surgery 74:251–258, 1984.*

3. *Hage JJ, de Graaf FH: Addressing the ideal requirements by free flap phalloplasty: Some reflections on refinements of technique. Microsurgery 14:592–598, 1993.*

4. *Sadove RC, McRoberts JW: Total phallic reconstruction with the free fibula osteocutaneous flap. Plastic and Reconstructive Surgery 89: 1001, 1992.*

5. *Sadove RC, Sengezer M, McRoberts JW, Wells MD: One-stage total penile reconstruction with a free fibula osteocutaneous flap. Plastic and Reconstructive Surgery 92:1314–1323, 1993.*

6. *Hage JJ, Winters HAH: Salvage of a "free flap" phalloplasty by distal arteriovenous fistula: case report. Journal of Reconstructive Microsurgery 12:279–282, 1996.*

7. *Hage JJ: One-stage total penile reconstruction with a free sensate osteocutaneous fibula flap—invited discussion. Plastic and Reconstructive Surgery 92:1324–1325, 1993.*

8. *Hage JJ, Bloem JJAM: Review of the literature on construction of a neo-urethra in female-to-male transsexuals. Annals of Plastic Surgery 30:278–286, 1993.*

9. *Hage JJ, Bouman FG, Bloem JJAM: Preconstruction of the pars pendulans urethrae for phalloplasty in female-to-male transsexuals. Plastic and Reconstructive Surgery 91:1303–1307, 1993.*

10. *Fang R-H, Lin J-T, Ma S: Phalloplasty for female transsexuals with sensate free forearm flap. Microsurgery 15:349–352, 1994.*

11. *Hage JJ: Phalloplasty for female transsexuals (letter). Microsurgery, 15:895, 1994.*

12. *Hage JJ: Reinnervation of the cutaneous part of the free fibula osteocutaneous flap for reconstruction of the phallus (letter). Plastic and Reconstructive Surgery 91:193, 1993.*

13. *Sadove RC: Reinnervation of the cutaneous part of the free fibula osteocutaneous flap for reconstruction of the phallus—reply. Plastic and Reconstructive Surgery 91:193, 1993.*

14. *Woerdeman LAE, Chaplin BJ, Griffioen FMM, Bos KE: De vrije sensibele osteocutane fibulalap; een anatomisch onderzoek naar de sensibele innervatie. Nederlands Tijdschrift voor Geneeskunde (Amsterdam), 140:640, 1996.*

15. *Woerdeman LAE, Chaplin BJ, Griffioen FMM, Bos KE: The free sensate osteocutaneous fibula flap: An anatomic study of the sensate innervation. Head and Neck (accepted for publication).*

16. *Hage JJ: Reinnervation of the cutaneous part of the free fibula flap (letter). Plastic and Reconstructive Surgery (accepted for publication).*

17. *Rhee J, Weisz D, Moscoso JF, Sinha UK, Biller HF, Urken ML: Intraoperative neurosome mapping of osteocutaneous free flaps – definition of 2 new sensate flaps (abstract), in 4th International Conference on Head and Neck Cancer, Toronto, Canada, July 28th– August 1st, 1996. Final Program and Abstract Book. Toronto, The Society of Head and Neck Surgeons, 1996.*

18. *Spalteholz W: Handatlas der Anatomie des Menschen, Vol. 3. Leipzig, Germany, Hirzel, 1993, pp 854–855.*

19. *Bell-Krotoski J, Tomancik E: The repeatability of testing with Semmes-Weinstein monofilaments. Journal of Hand Surgery 12A: 155–161, 1987.*

20. *Gilbert DA, Winslow BH, Gilbert DM, Jordan GH, Horton CE: Transsexual surgery in the genetic female. Clinics in Plastic Surgery 15: 471–487, 1988.*

21. *Hage JJ, Bouman FG, de Graaf FH, Bloem JJAM: Phalloplasty in female-to-male transsexuals: The Amsterdam experience. Journal of Urology 149:1463–1468, 1993.*

22. *Hage JJ, Bloem JJAM, Bouman FG: Obtaining rigidity in the neophallus of female-to-male transsexuals: A review of the literature. Annals of Plastic Surgery 30:327–333, 1993.*

23. *Dubin BJ, Sato RM, Laub DR: Results of phalloplasty. Plastic and Reconstructive Surgery 64:163–170, 1979.*

24. *Biemer E: Transsexualismus: geslechtsumwandelnde Operationen. Medische Klinik 77:468–474, 1982.*

25. *Fisch M, Wammack R, Ahlers J, Sennrich T, Muller SC, Hohenfellner R: Osseous fixation of a penile prosthesis after transsexual phalloplasty: A case report. Journal of Urology 149:122–125, 1993.*

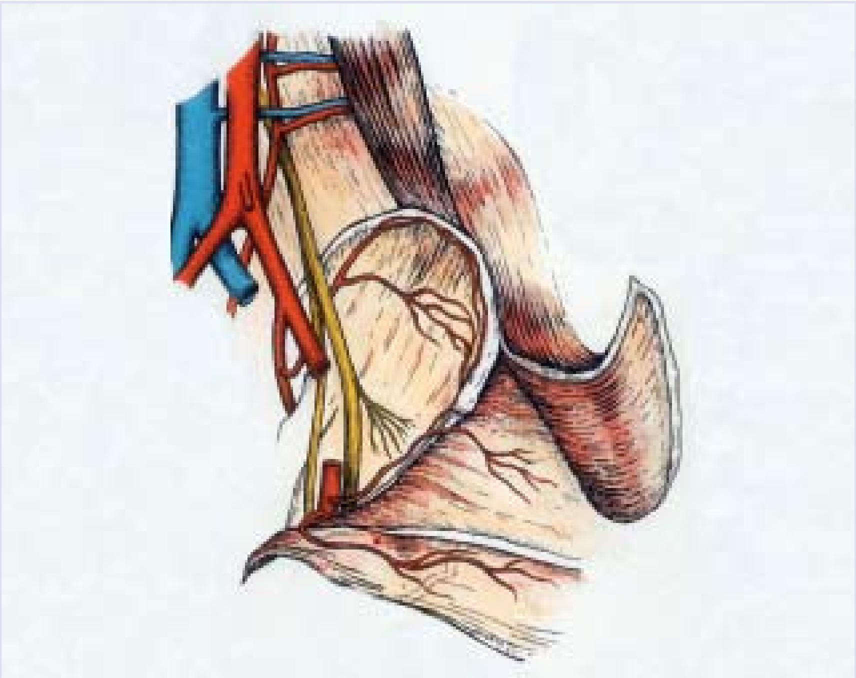
26. *Hage JJ, de Graaf FH, Bouman FG, Bloem JJAM: Sculpturing the glans in phalloplasty. Plastic and Reconstructive Surgery 92:157–161, 1993.*

27. *Goodacre TEE, Walker CJ, Jawad AS, Jackson AM, Brough MD: Donor site morbidity following osteocutaneous free fibula transfer. British Journal of Plastic Surgery 43:410–412, 1990.*

28. *Anthony JP, Rawnsley JD, Benhaim P, Ritter EF, Sadowsky SH, Singer MI: Donor leg morbidity and function after fibula free flap mandible reconstruction. Plastic and Reconstructive Surgery 96:146– 152, 1995.*

4

The bipedicled iliac crest flap



4 The bipedicled iliac crest flap

Henri A.H. Winters, Ludwig E. Smeele, and Charles R. Leemans

Abstract

The use of the iliac crest flap based on the deep circumflex iliac artery and vein is well established in orofacial reconstruction. In cases where the deep circumflex iliac artery and vein are of inadequate size, or when large composite flaps are required, vascular augmentation can be achieved using the iliac branches of the iliolumbar artery and vein as an additional pedicle. Routine inclusion of this additional pedicle in iliac crest flaps creates extra safety with a low effort.

Introduction

The free vascularized iliac crest flap based on the deep circumflex iliac vessels has proven its value in reconstructive procedures. One of its advantage is the alleged consistency of its vascular pedicle.[1,2] In general, preoperative angiograghy is not performed. In some patients, however, the deep circumflex iliac artery and vein are of such small size that they are insufficient as a pedicle for a large composite flap. The overlap between the various vascular systems providing the iliac crest allows the possibility of using an alternative or additional pedicle. At least six vascular systems contribute to the iliac crest.

They are:

1. *the deep circumflex iliac vessels;*
2. *the superficial circumflex iliac vessels;*
3. *the lumbar/costal vessels;*
4. *the superior gluteal vessels;*
5. *the transverse branches of the lateral femoral circumflex vessels;*
6. *the iliac branches of the iliolumbar vessels.*

The first five systems have been used as pedicles for transplantation of iliac bone, albeit not all of these alternatives are thought to be equally suitable for microsurgical transplantation.[3-7]

Theoretically, the sixth system, the iliac branches of the iliolumbar vessels, is also suitable as a pedicle for the iliac crest flap. The length of the pedicle is 5 to 6 cm and the vessels range in diameter from 1 to 3 mm. They are situated in the loose connective tissue over the iliacus muscle and can be easily dissected. Significant extra operation time is needed only when these vessels are actually used as an additional pedicle and microsurgical anastomoses are performed. In our hands, this additional pedicle has proven its value in clinical use.

Case report

A 42-year-old female was operated on for a T4 N2c M0 squamous cell carcinoma of the oral cavity, with involvement of the mandible and overlying skin.
A segmental mandibulectomy and bilateral modified neck dissection were performed, leaving a mandibular defect of 14 cm, as well as a defect in the anterior floor of mouth and an 8- x 12-cm skin defect of the chin. A composite iliac crest osteomyocutaneous flap was used for primary reconstruction. Fourteen centimeters of iliac crest was harvested, in combination with the major part of the oblique abdominal muscle and an 8- x 12-cm skin island.
In this case, the deep circumflex iliac vessels were thought to be insufficient for such a large flap. It was decided to use the well-developed iliac branches of the iliolumbar artery and vein as an additional pedicle. A length of 6 cm of this iliolumbar pedicle could be obtained. On irrigation of the deep circumflex iliac artery, the blood flow progressed through both the iliolumbar artery and vein and vice versa. Even the ascending branch of the deep circumflex iliac artery filled via the iliolumbar artery.
The deep circumflex iliac vessels were anastomosed to the left facial artery and internal jugular vein. The iliolumbar pedicle was anstomosed to the right-side facial artery and vein. Although it is difficult to quantify the effect of vascular augmentation, blood flow in the flap was clearly increased by the use of the additional iliolumbar pedicle. The floor of the mouth was reconstructed with the internal oblique abdominal muscle, and the skin island of the flap was adapted to fit the skin defect over the chin. Uneventful healing followed.

Anatomy

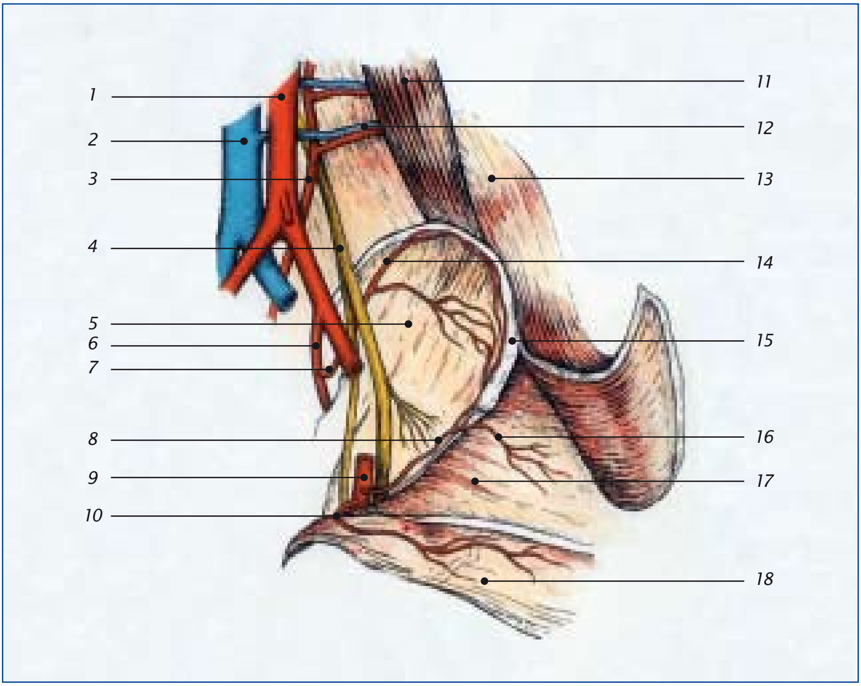
The iliolumbar artery branches from the posterior trunk of the internal iliac artery *(Fig. 1)*. It ascends laterally, anterior to the sacro-iliac joint and lumbosacral trunk and posterior to the external iliac vessels. After reaching the medial border of the psoas major muscle, it divides into a lumbar and an iliac branch. The latter supplies the iliac muscle and also gives off a large nutrient branch which enters the iliac bone. In the region of the iliac crest, the iliac branch of the iliolumbar artery anastomoses with the superior gluteal artery and the deep circumflex iliac artery.[8,9]

Discussion

The iliolumbar vessels are situated in the loose connective tissue over the iliacus muscle and can be easily dissected. We always include the iliac branches of the iliolumbar vessels in our iliac crest flaps as a safety measure *(fig. 2)*. No additional incisions or extensive dissection are necessary. The amount of extra time needed is about 15 min. This is an advantage over the use of other alternative pedicles. Since the iliac crest flap based on the deep circumflex iliac vessels is a safe flap with an adequate vascular supply in most cases, anastomosis of the

Figure 1.
Vascular anatomy of the pelvic region.

1 *aorta;*
2 *inferior vena cava;*
3 *ascending lumbar vein ;*
4 *femoral nerve ;*
5 *iliacus muscle ;*
6 *internal iliac artery ;*
7 *iliolumbar artery ;*
8 *deep circumflex iliac artery ;*
9 *external iliac artery;*
10 *inferior epigastric artery;*
11 *quadratus lumborum muscle;*
12 *lumbar artery and vein;*
13 *transverse abdominal muscle;*
14 *iliac branches of iliolumbar artery;*
15 *iliac crest;*
16 *ascending branch of deep circumflex artery;*
17 *internal oblique abdominal muscle;*
18 *rectus abdominis muscle.*



additional pedicle is normally not necessary. However, in those cases in which an inappropriate pedicle is encountered, the iliac branches of the iliolumbar vessels can be used as an additional or even alternative pedicle. We have no experience in the use of these iliac branches as sole pedicle for the iliac crest flap, but this appears to be a safe possibility because of the vascular anatomy. In case the ascending branch of the deep circumflex iliac artery is preserved, it should, theoretically, even be possible to include the internal oblique abdominal muscle as part of the flap. The flow in the deep circumflex iliac artery would then be reversed.

Conclusion

Inclusion of the iliac branches of the iliolumbar vessels in the iliac crest flap is a safety measure that will take hardly any additional surgery, but provides extra security.

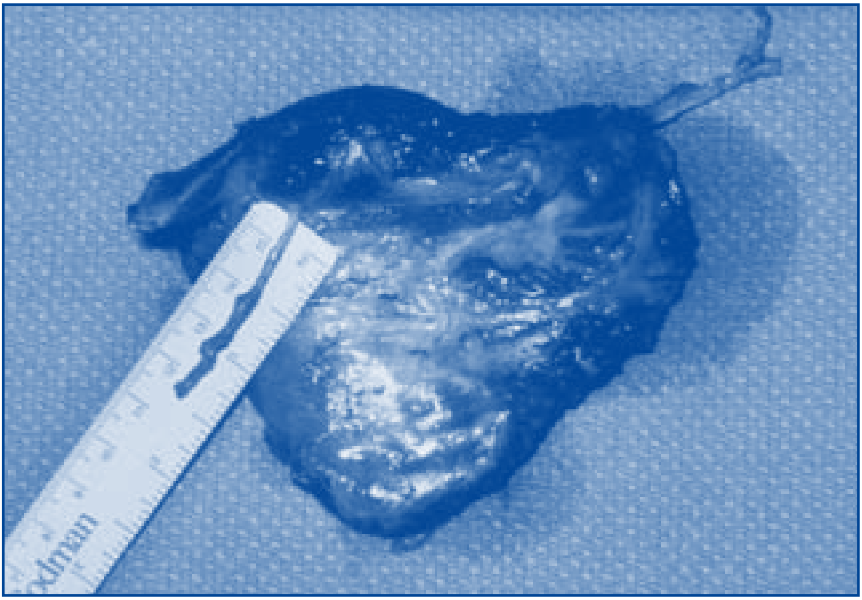


Figure 2
The iliac branches of the iliolumbar vessels as an additional pedicle in an iliac crest flap (ruler).

References

1. *Taylor GI, Townsend P, Corlett R: Superiority of the deep circumflex iliac vessels as the supply for free groin flaps: Experimental work. Plast Reconstr surg 64:595,1979*

2. *Taylor GI, Townsend P, Corlett R: Superiority of the deep circumflex iliac vessels as the supply for free groin flaps: Clinical work. Plast Reconstr Surg 64:745, 1979*

3. *Huang G-K, Hu R-Q,Miao H, et al.: Micorvascular free transfer of iliac bone based on the deep superior branches of the superior gluteal vessels. Plast Reconstr Surg 75:68, 1985*

4. *Hayashi A, Maruyama Y, Okajima Y, Montegi M: Vascularised iliac bone graft bases on a pedicle of upper lumbar vessels for anterior fusion of the thoracolumbar spine. Br J Plast Surg 47:425, 1994*

5. *Zhao J: Free iliac skin flap transplantation by anastromosing the fourth lumbar blood vessel. Plast reconstr Surg 77:836, 1986*

6. *Baker SR: Reconstuction of mandibular defects with the revascularised free tensor fascia lat osteomyocutaneous flap. Arch Otolaryngol 107:414, 1981*

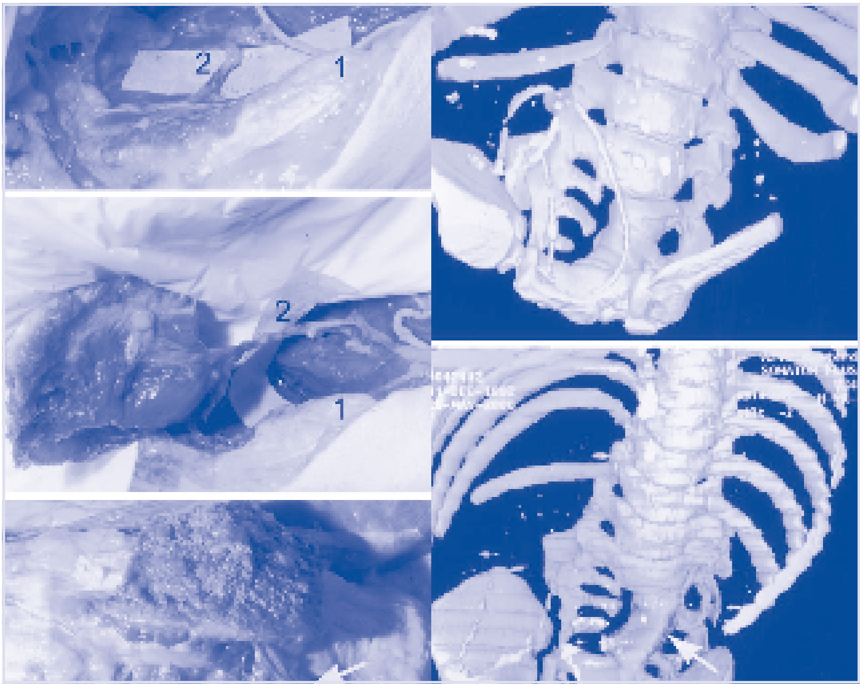
7. *Urken M: Composite free flaps in oromandibular reconstruction: review of the literature. Arch Otolaryngol Head Neck Surg 117:724, 1991*

8. *Paturet G: Appareil circulatoire. In : Traité d'Anatomie Humaine. Paris : Masson & Cie.,1958, pp 543-582*

9. *Sobotta J, Becher H : Atlas der Anatomie des Menschen. Munchen-Berlin-Wien : Urban & Schwarzenberg' 1973*

5

The Iliolumbar Artery as the Nutrient Pedicle for an Iliac Crest Graft: A New Technique in Reconstruction of the Lumbar Spine



5 The Iliolumbar Artery as the Nutrient Pedicle for an Iliac Crest Graft: A New Technique in Reconstruction of the Lumbar Spine

Winters, Henri A. H. M.D.; van Harten, Sabine M. M.D.; van Royen, Barend J. M.D., Ph.D.

Abstract

A new technique for lumbar spinal reconstruction with a pedicled iliac crest flap is introduced. The iliac branches of the iliolumbar artery can be used as the nutrient pedicle for an iliac crest flap. This flap has distinct advantages in lumbar spinal reconstruction: It can easily reach the vertebral column due to the posterior location of the pedicle and the vessels are easy to identify and to dissect. We used this flap for an anterior spinal fusion in a 6 ½ year old girl with progressive kyphosis.

Introduction

The iliac crest is a commonly used donor site for vascularized bone in reconstructive surgery. Vascularized bone grafting has offered significant advantages over nonvascularized bone grafting: a more rapid bony consolidation and healing occur, thereby decreasing morbidity.(1-4) A vascularized iliac crest flap can be used either as a free or as a pedicled flap. Flaps of different composition, based on a variety of pedicles, have been described.(5-13) Whenever they dissected a deep circumflex iliac artery flap, the authors observed the iliac branches of the iliolumbar artery to be a constant and reliable pedicle to the iliac crest. This suggested their suitability for use as a sole nutrient pedicle, which led to the publication of the first clinical use of this pedicle in 1998.(11) This use of the iliac branches of the iliolumbar artery has since been confirmed in an anatomic study by Chen et al.(14) In this report, a new technique for the reconstruction of the lumbar spine is introduced using the iliac branches of the iliolumbar artery as the sole nutrient pedicle for an iliac crest flap.

Anatomy

The iliolumbar artery originates from the internal iliac artery. It runs obliquely upward, deep to the external iliac vessels between the obturator nerve and the lumbosacral plexus, and then crosses deep to the psoas major muscle. In the majority of cases, when reaching the lateral border of the muscle, the iliolumbar artery runs between the iliac fascia and the iliac muscle toward the iliac crest supplying both muscle and bone. Chen et al. found that in 20 percent of cases, the iliolumbar artery ran deep to the iliac muscle, and then the anterior branch of the fourth lumbar artery was the major nutrient pedicle to the middle part of the iliac crest. The iliolumbar artery has a length of 7.0 ± 3.9 cm and an external diameter of 2.0 ± 0.4 mm.[14]

Surgical Technique

An incision is made along the iliac crest. The oblique abdominal muscles are incised in the line of its fibers near their attachments and are pulled medially. The peritoneum and its contents are retracted cranially. The iliac branches of the iliolumbar artery and vein are identified in the loose connective tissue over the iliac muscle, approximately 6 cm dorsal to the anterior superior iliac spine *(Fig. 1, upper)*. Using the entry of these vessels in the iliac muscle as a center, incisions are made over the intended osteotomy sites. A small cuff of iliac muscle should be left in situ at the inside of the iliac crest to preserve bone vascularization *(Fig. 1, center)*. Osteotomies are then performed, dissecting the desired portion of the iliac crest. Monocortical, bicortical, and tricortical flaps can be harvested; then the pedicle is mobilized until the lumbar spine is reached *(Fig. 1, lower)*.

Case Report

A 6-year-old girl with spina bifida suffered from severe progressive kyphosis of the lumbar spine (Fig. 2, left). A dorsal spondylodesis at L2 to L4 was performed with instrumentation and allogenic bone. Two months after the first operation, a vascularized iliac crest flap was used to establish ventral stabilization to prevent further progression of the kyphosis. The patient was put in a supine position slanted to the contralateral side with a slight ventral curve. The lumbar vertebrae were exposed from L1 to

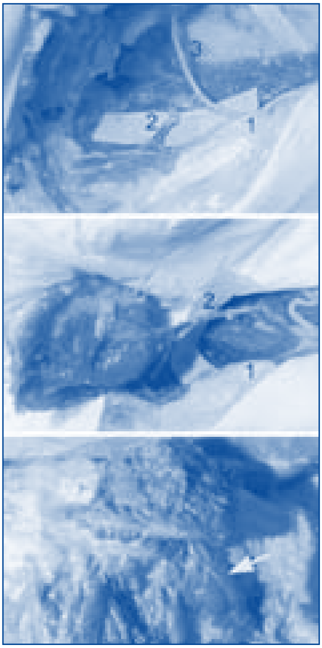


Fig. 1. (upper) The iliolumbar artery and vein, shown in a cadaver dissection. 1, anterior superior iliac spine; 2, ilio-lumbar artery and vein;3, lateral cutaneus femoral nerve. (Center) To preserve the vascularization of the bone, a small cuff of iliac muscle should be left in situ. 1, anterior superior iliac spine;2, iliolumbar artery and vein. (lower) After dissection of the vascular pedicle (arrow), the flap can easily reach the lumbar spine, as demonstrated in this cadaver dissection, in which the psoas muscle is partly removed.

L5 using a retroperitoneal approach through an incision over the left iliac crest, transecting the oblique abdominal muscles. The disci from L2/L3 to L4/L5 were dissected, and a slot was made on the anterior side of the spine from L1 to L5. The iliac branches of the iliolumbar artery and vein were identified. A bicortical iliac crest flap was harvested, preserving the outer table of the iliac bone. Persistent oozing was observed from the cut surfaces of the bone flap, proving adequate vascularization. Next, the pedicle was mobilized until the slot in the spinal column was reached. The flap was tailored to size and pressed tightly into the slot. Cancellous bone from the donor site was added. No further fixation was used, and the incision was closed in layers. No complications were seen postoperatively. The patient was mobilized in a corset for 3 months, and no further progress of the deformity was observed. A three-dimensional computed tomographic scan 10 months postoperatively showed good consolidation *(Fig. 2, right)*.

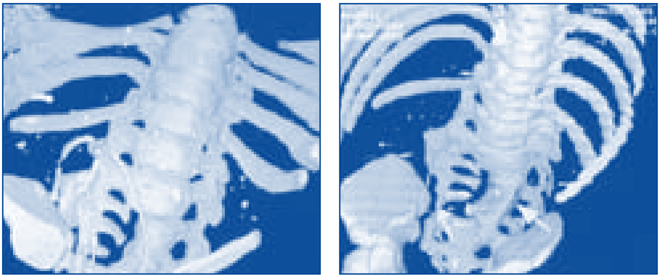


Fig. 2. (left) A three-dimensional computed tomographic scan of the vertebral column of a 6-year-old girl with progressive kyphosis of the lumbar spine. (right) A three-dimensional computed tomographic scan 10 months postoperatively showing good consolidation of the bony flap (arrow).

Discussion

Vascularized reconstruction of the lumbar spine has been performed with fibula, iliac crest, and rib.[4,5,12,15,16] The fibula provides strong cortical bone, but its use in the spinal column requires surgical revascularization, making it a long, complicated operation.
Both the rib and iliac crest can be used as pedicled flaps without the need for microvascular anastomosis. The pedicled rib flap has the disadvantage of being curved and not very strong. Also, the limited reach of the pedicle length restrains its use in reconstruction of the lumbar spine.
As a variety of vessels contribute to its blood supply, the iliac crest can be used in several ways in lumbar spine reconstruction. The deep circumflex iliac artery is the most common pedicle for iliac crest flaps. For reconstruction of the lumbar spine, however, it is useless because of its anatomic position. For the

same reason, the superior gluteal vessels are not suitable as a pedicle. Hayashi et al.[5] raised a vascularized iliac bone flap with a pedicle of the internal oblique muscle based on the upper lumbar vessels. Their technique requires dissection of the ascending branch of the deep circumflex iliac artery, making it a difficult and time-consuming procedure. Yelizarov et al.[12] described the use of the posterior portion of the iliac crest flap based on a pedicle of quadratus lumborum muscle as a useful option. The fourth lumbar artery has been used as a sole nutritive pedicle to an iliac bone flap and may be well suited for reconstruction of the lumbar spine.[13,14] When the iliolumbar artery runs deep to the iliac muscle, as Chen et al. found in 20 percent of their cases, the fourth lumbar artery can be a valuable alternative. In this way, major changes in the operative procedure can be avoided. A disadvantage of the lumbar-based pedicles is the questionable reliability after previous spinal surgery, because of their vulnerability in surgery of the vertebral column.
The iliac branches of the iliolumbar artery are a suitable alternative as a nutritive pedicle in iliac crest flaps. They have sufficient length and diameter and are easy to identify and dissect because they are situated in the loose connective tissue over the iliac muscle. In lumbar spinal surgery, their use has the distinct advantage of its posterior localization, which makes it easy to rotate the pedicle toward the vertebral column without tension. Also, it is highly unlikely that this pedicle will have been damaged in previous spinal surgery. We think that in reconstruction of the spine, the iliac branches of the iliolumbar artery are the vessels of choice for a pedicled iliac crest flap.

References

1. *Han, C. S., Wood, M. B., Bishop, A. T., et al. Vascularized bone transfer. J. Bone Joint Surg. (Am.) 74: 1441, 1992. ExternalResolverBasic Bibliographic Links*

2. *Shaffer, J. W., Field, G. A., Goldberg, V. M., et al. Fate of vascularized and nonvascularized autografts. Clin. Orthop. 197: 32, 1985. Ovid Full Text ExternalResolverBasic Bibliographic Links*

3. *Weiland, A. J., Moore, J. R., and Daniel, R. K. Vascularized bone autografts: Experience with 41 cases. Clin. Orthop. 174: 87, 1983. Ovid Full Text ExternalResolverBasic Bibliographic Links*

4. *Wuisman, P. I. J. M., Jiya, T. U., van Dijk, M., et al. Free vascularized bone graft in spinal surgery: Indications and outcome in eight cases. Eur. Spine J. 8: 296, 1999. ExternalResolverBasic Bibliographic Links*

5. *Hayashi, A., Maruyama, Y., Okajima, Y., and Motegi, M. Vascularised iliac bone graft based on a pedicle of upper lumbar vessels for anterior fusion of the thoraco-lumbar spine. Br. J. Plast. Surg. 47: 425, 1994.*

6. *Huang, G. K., Hu, R. Q., Miao, H., et al. Microvascular free transfer of iliac bone based on the deep superior branches of the superior gluteal vessels. Plast. Reconstr. Surg. 75: 68, 1985. Ovid Full Text ExternalResolverBasic Bibliographic Links*

7. *Huang, G. K., Liu, Z. Z., Shen, Y. L., et al. Microvascular free transfer of iliac bone based on the deep circumflex iliac vessels. J. Microsurg. 2: 113, 1980. ExternalResolverBasic Bibliographic Links*

8. *Stock, W., Hierner, R., Dielert, E., et al. The iliac crest region: Donor site for vascularized bone periosteal and soft tissue flaps. Ann. Plast. Surg. 26: 105, 1991. Ovid Full Text ExternalResolverBasic Bibliographic Links*

9. *Taylor, G. I., Townsend, P., and Corlett, R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps: Experimental work. Plast. Reconstr. Surg. 64: 595, 1979.*

10. *Taylor, G. I., Townsend, P., and Corlett, R. Superiority of the deep circumflex iliac vessels as the supply for free groin flaps: Clinical work. Plast. Reconstr. Surg. 64: 745, 1979. Ovid Full Text ExternalResolverBasic Bibliographic Links*

11. Winters, H. A. H., Smeele, L. E., and Leemans, C. R. The bipedicled iliac crest flap. J. Reconstr. Microsurg. 12: 257, 1996. ExternalResolverBasic Bibliographic Links

12. Yelizarov, V. G., Minachenko, V. K., Gerasimov, O. R., et al. Vascularized bone flaps for thoracolumbar spinal fusion. Ann. Plast. Surg. 31: 532, 1993. Ovid Full Text ExternalResolverBasic Bibliographic Links

13. Zhao, J. T. Free iliac skin flap transplantation by anas- tomosing the fourth lumbar blood vessel. Plast. Reconstr. Surg. 77: 836, 1986.

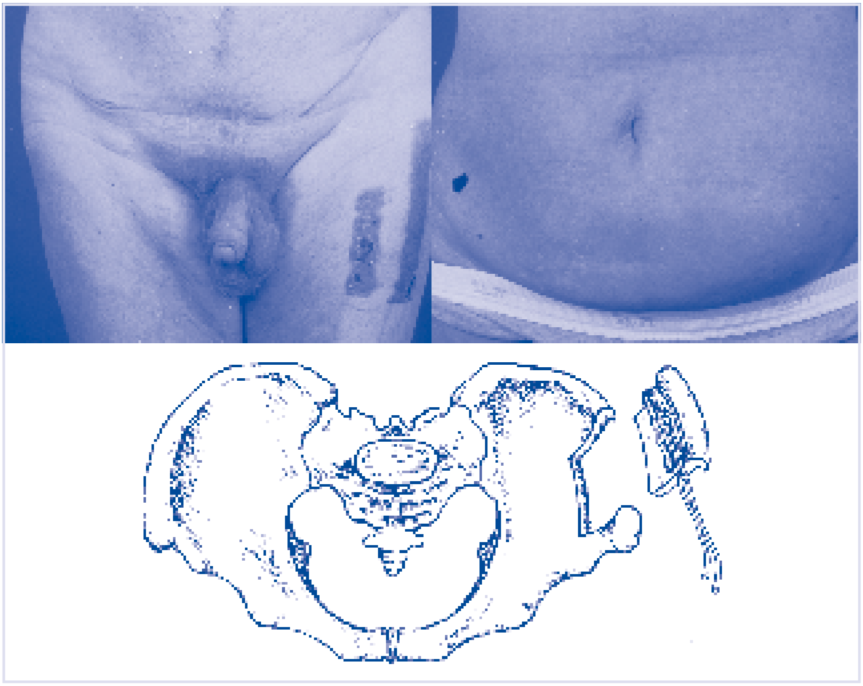
14. Chen, R. S., Liu, Y. X., Liu, C. B., et al. Anatomic basis of iliac crest flap pedicled on the iliolumbar artery. Surg. Radiol. Anat. 21: 103, 1999.

15. Bradford, D. S., and Dahler, Y. H. Vascularized rib grafts for stabilisation of kyphosis. J. Bone Joint Surg. (Br.) 68: 357, 1986. ExternalResolverBasic Bibliographic Links

16. Nijland, E. A., van den Berg, M. P., Wuisman, P. I., et al. Correction of a dystrophic cervicothoracic spine deformity in Recklinghausen's disease. Clin. Orthop. 349: 149, 1998. Ovid Full Text ExternalResolverBasic Bibliographic Links

6

Reduction of donor site morbidity of the iliac crest free flap by preservation of the anterior superior iliac spine



6 Reduction of donor site morbidity of the iliac crest free flap by preservation of the anterior superior iliac spine

H.A.H. Winters, L.E. Smeele

Abstract
To reduce donor site morbidity in the iliac crest free flap, we suggest leaving the anterior superior iliac spine in situ. The advantages are: less tension on the wound, less pain, faster rehabilitation, preservation of the ability to wear pants without braces, and a better cosmetic result through preservation of contour.

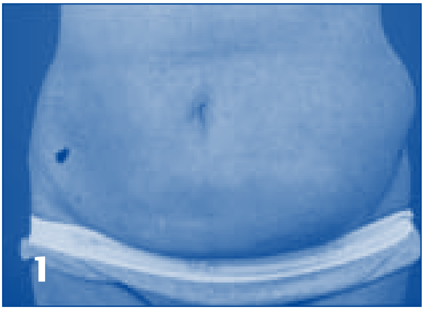
Introduction
The iliac crest flap, based on the deep circumflex iliac artery, is a versatile flap in reconstructive surgery[3-6]. Pain, gait disturbance, lateral thigh paraesthesia, femoral nerve weakness, and herniation or weakness of the abdominal wall have been described as the main donor site complications, albeit in low incidence[1-4]. So far, little attention has been paid to the remaining contour deformity and its functional implications. The iliac crest, specifically the anterior superior iliac spine (ASIS) determines the normal contour of the pelvic region. Removal of the ASIS will change this contour *(Fig. 1)*. This will not only result in an unpleasing, asymmetrical appearance, but also in impaired function. The ASIS represents the main origin of the anterior musculature of the thigh. If the ASIS is removed, these muscles have to be attached to those of the abdominal wall. This results in tension on the wound and difficulty and pain in walking, often for a longer period of time. Another, less dramatic but very inconvenient, functional impairment was illustrated by one of our male patients, who underwent mandibular reconstruction with an iliac crest free flap after excision for oral cancer. He complained that he could not wear his pants anymore without the use of braces. His pants slid off his hip due to lack of contour. For these reasons, we have modified the surgical technique, leaving the anterior superior iliac spine in-situ, in order to preserve contour and functional anatomy, thereby reducing donor site morbidity *(Fig. 2)*.

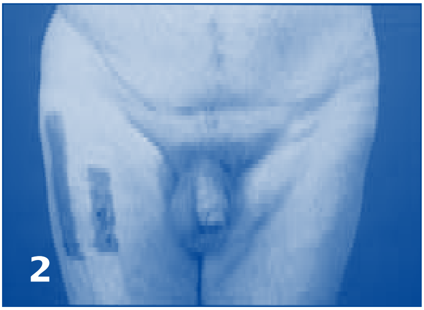
Surgical technique
The standard surgical technique for raising the iliac crest flap may be followed. The inguinal ligament is detached from the ASIS and left in continuity with the abdominal wall. This will provide good access to the vascular pedicle.
To harvest the bony part of the flap, the bony incision is started 1.5 cm dorsal to the ASIS and can be perpendicular to the iliac crest. This will not weaken the remaining ASIS. The incision is continued as usual *(Fig. 3)*. After lifting the flap,

the transverse fascia is sutured to the iliac muscle. The inguinal ligament can be easily and strongly reattached to the ASIS without the need for drill holes, thus restoring the inguinal region to its normal anatomy with one key suture that will also take the tension of the more lateral part of the aponeurosis of the external oblique abdominal muscle. Finally, the internal and external oblique muscles are sutured to the fascia of the gluteal musculature.

Discussion

In reconstructive surgery, donor site morbidity cannot always be avoided.
The lack of alternatives sometimes justifies the introduction of minor or major physical disabilities, especially in oncologic surgery. However, it is the surgeon's duty to limit donor site morbidity as much as possible, and to look for variations and new techniques to achieve this.
The modification we present has the following advantages: The closure of the abdominal wall is facilitated; the anatomy of the thigh muscles is not changed, preserving normal function and therefore giving less pain and faster rehabilitation; symmetry and contour are optimized, giving a pleasing cosmetic result and the function of the ASIS as a suspension for pants and a belt is kept intact.
In 24 patients there was one specific complication related to this technique. In a 70-year-old woman, a fracture of the ASIS was diagnosed 2 months after the initial operation. The anterior cut had not been positioned far enough posteriorly, leaving the base of the preserved ASIS less than 1 cm wide. Conservative treatment of this fracture led to herniation of the abdominal wall, which needed secondary surgery. Of course, one of the best ways to minimize donor site morbidity is to use only the inner cortex of the iliac crest(4). This method is used by the authors whenever possible. However, sometimes the situation calls for a bicortical iliac crest bone graft. In those cases we would strongly recommend the use of our modification to reduce the donor site morbidity associated with this flap.





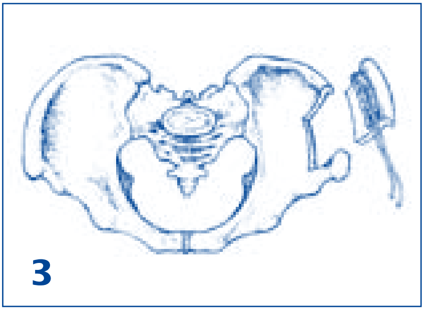


Fig. 1 Contour deformity due to removal of a bicortical iliac crest flap, including the anterior superior iliac spine

Fig. 2 Contour is hardly changed when the anterior superior iliac spine is preserved

Fig. 3 Position of bony incisions in a bicortical iliac crest flap

References

1. *Colen SR, Shaw WW, McCarthy JG (1986) Review of the morbidity of 300 free flap donor sites. Plast Reconstr Surg 77: 6*

2. *Cowley SP, Anderson LD (1983) Hernias through donor sites for iliac bone grafts. J Bone Joint Surg [AM] 65: 7*

3. *Jewer DD, Boyd JB, Manktelow RT, et al (1984) Orofacial and mandibular reconstruction with the iliac crest free flap. Plast Reconstr Surg 84: 3*

4. *Shenaq SM, Klebuc MJA (1994) Refinements in the iliac crest microsurgical free flap for oromandibular reconstruction. Microsurgery 15: 825–830*

5. *Urken ML (1991) Composite free flaps in oromandibular reconstruction. Arch Otolaryngol Head Neck Surg 117: 724–732*

5. *Urken ML, Weinberg H, Vickery C, et al (1991) Oromandibular reconstruction using microvascular composite free flaps. Arch Otolaryngol Head Neck Surg 117: 733–742*

7

Maxillary reconstruction using a horizontally placed iliac crest flap

7 Maxillary reconstruction using a horizontally placed iliac crest flap

H. A. H. Winters, S. M. Harten

Abstract

High maxillectomy defects with preservation of the orbital contents are disabling and tend to cause ocular problems because of the lack of support. Reconstruction should provide support to the orbital contents, restore facial symmetry, and eliminate the oronasal fistula. A wide range of flaps have been described for the reconstruction of these challenging defects. We used a horizontally placed deep circumflex iliac artery free flap with internal oblique muscle in four patients. This is a reliable method, the flap is easy to harvest, and the donor side is minimized by using only the inner table of the iliac crest.

Introduction

Reconstruction of maxillary or midfacial defects is a challenging and difficult task, especially when the orbital floor is removed while the orbital contents are preserved: high maxillectomy defects, class 3 according to Brown's[(2)] classification. The lack of support for the orbital contents leads to secondary displacement of the eye globe and visual impairment. The aim of a good reconstruction is to provide support to the orbital contents, to restore facial symmetry, and to obliterate communication between oral and nasal cavity, thereby improving mastication and speech. To achieve this, reconstruction of the bony orbital floor including the lower orbital rim and the zygomatic arch is necessary. When possible, enough bone should be provided to support future osseointegrated dental implants. Closure of the oronasal fistula can be achieved with bone and soft tissue or by soft tissue alone, or with an obturator in a later procedure. Iliac crest flaps offer vascularized bone and soft tissue by means of the internal oblique muscle. This flap has been used for maxillary defects in several ways. In this report we present four cases of secondary reconstruction of the orbital floor and maxilla with a horizontally placed vascularized split inner cortex iliac crest flap, including the internal oblique muscle.

Operative procedure

An incision is made over the contralateral iliac crest. The external oblique muscle is exposed and the inguinal ligament is detached from the ASIS. The external oblique muscle is cut from the iliac crest and reflected cranially to expose the deep circumflex iliac artery and deep circumflex iliac vein. The vascular pedicle is dissected, sparing the lateral cutaneous femoral nerve. The internal oblique muscle

is freed from the external oblique muscle, transected just under the lower rib, and then dissected from the transverse muscle downwards to the iliac crest, carefully preserving and including the ascending branch of the deep circumflex iliac artery, which bifurcates from the parent artery approximately 1 cm before the ASIS. Variation in size, number, and origin of this vessel requires cautious dissection[16]. The transverse muscle is cut from the iliac crest; a small cuff of iliac muscle is preserved to avoid damage to the pedicle and to ensure a good vascularization of the bone graft. Three perpendicular cuts are made on the internal side of the iliac bone. The inner table is osteotomized using an osteotome or saw. The anterior cut is made 1.5–2 cm from ASIS preserving the insertions of the muscles and ligaments of the lower extremity. The bone is then osteotomized between inner and outer table including most of the iliac crest in the flap, but preserving the contour of the pelvis. The bone is cut to size in a trapezoidallike shape to fit the facial defect, taking advantage of the natural contour of the iliac crest to form the lower orbital rim. The flap is inserted into the maxillary defect in a horizontally position, with the bony portion covered by the muscle providing nasal and oral lining *(Figs. 1, 2)*. The muscle is wrapped around the bone to cover the dorsal edge of it and to fill up the rest of the maxillectomy defect. Medially the muscle is sutured to the contralateral remnant of the palate to close the oronasal communication.
The bone is fixed to the remains of the zygomatic arch laterally and to the nasal bone medially. Titanium plates or wires are used for fixation. The vascular pedicle is tunneled through the cheek and anastomosed to the ipsilateral facial artery and vein. When a radical neck dissection is performed, and no acceptor vessels are available in the ipsilateral neck, the pedicle can be tunneled through the upper lip and anastomosed to the contralateral facial vessels. In this case an ipsilateral iliac crest flap should be used.

Patients

This technique was used in four patients with a maxillectomy defect with preservation of the orbital contents between May 1995 and March 2001 at the Department of Plastic and Reconstructive Surgery of the VU Medical Center, Amsterdam.

Case 1

In February 1994 a high left-sided maxillectomy (class 3a) for a moderately differentiated squamous cell carcinoma was performed in a 36-year-old woman. The ablation of the tumor was performed by the Ferguson-Weber approach. The orbital contents were supported by the transposed temporalis muscle flap, and the defect was covered by a split skin graft. Postoperatively she received radiotherapy because of tumor growth in the resection margins. In May 1995 she was admitted to our department for a reconstructive procedure. At the time of admission she presented with an important facial asymmetry, vertical dystopia of the left eye with diplopia and enophthalmos, ectropion of the lower eyelid, and a nasocutaneous fistula. Reconstruction was performed with a vascularized split inner iliac crest cortex flap based on the deep circumflex iliac artery with internal oblique muscle. The bony portion of the flap, covered by the internal oblique muscle flap, was fixed in a horizontal position with wires to the nasal bone and with miniplates and screws to the stump of the zygomatic arch. A separate submandibular incision was made in the old scar and the facial vessels were dissected out. The vascular pedicle was tunneled submucosally through the cheek to this incision and anastomosed to the facial artery and vein. Recovery was uneventful but for the recurrence of the nasocutaneous fistula which was managed using a glabellar flap 6 months postoperatively. The patient has a good facial contour and an improvement in mastication and speech. No osseointegrated implants were given. The patient's diet is normal with no restrictions using a dental prosthesis.

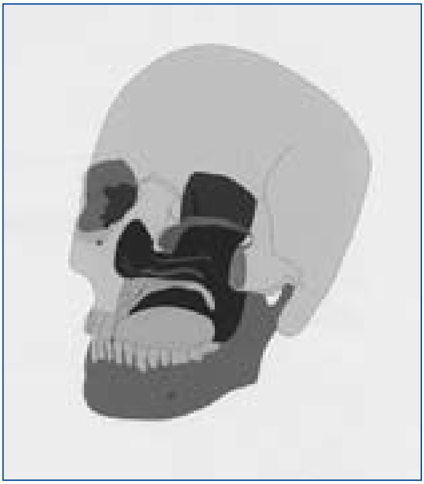


Fig. 1 High maxillectomy defect

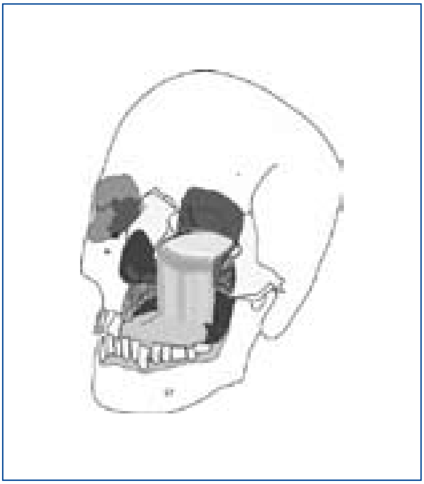


Fig. 2 The split inner cortex iliac crest flap is inserted into the maxillary defect in a horizontally position

Case 2

In February 1998 a 29-year-old woman underwent a high rightsided maxillectomy (class 3a) for a low-grade differentiated osteosarcoma with extension in the right infratemporal fossa. The defect was covered by a split skin graft. The right eye was supported by the periosteum of the orbital floor. Adjuvant chemotherapy was given pre- and postoperatively. In May 1999 reconstruction was performed. At the time of admission she presented with significant facial asymmetry, vertical dystopia with diplopia and enophthalmos. A vascularized split iliac crest inner cortex flap, covered by the internal oblique muscle flap, was used to fill the facial defect and to give support to the orbital contents. The bone was fixed using both titanium microplates and cerclage wire. A part of the muscle flap was used to reconstruct the palate. The vascular pedicle was anastomosed to the ipsilateral facial artery and vein. Recovery was uneventful both for the implant and donor site. After 5 months an intraoral scar revision was performed. After 3 years the right eye is in a normal position with no impaired vision. Facial contour has improved and facial symmetry is achieved. In this patient we discovered that the bony reconstruction did not have enough caudal projection to support osseointegrated dental implants. This was corrected in a secondary procedure using a nonvascularized bone graft in combination with hyperbaric oxygen. Following this four osseointegrated implants were successfully inserted, and complete dental rehabilitation was achieved.

Case 3

In October 1993 a high right-sided maxillectomy for a moderately differentiated squamous cell carcinoma was performed in a 32-year-old patient. The hard palate was excised beyond the midline including a part of the soft palate (class 3b). The defect was covered by a split skin graft, and no support was left for the orbital contents. Postoperatively the patient received radiotherapy. Ten months later a radical neck dissection was performed followed by another session of radiotherapy. The patient developed a striking facial asymmetry and significant right eye dystopia with diplopia and enophthalmos (Fig. 3a, b). In September 1999 a reconstructive procedure was performed using a vascularized split iliac crest inner cortex flap, covered by the internal oblique muscle. The muscle was used to reconstruct the palate. The bony part was fixed with titanium microplates and screws to the nasal bone and the remnants of the zygomatic arch. Because the patient underwent a radical neck dissection in the past, ipsilateral anastomosis of the vascular pedicle was not possible. Therefore the pedicle was tunneled through the upper lip and anastomosed to the contralateral facial artery and vein in the nasolabial sulcus. Recovery was uneventful. Correction of the eye dystopia and enophthalmos was achieved and facial symmetry was improved (Fig. 3c, d). No visual disturbances were noted in the early postoperatively assessment or later. Due to retraction of the internal oblique muscle a palatal fistula recurred. It was controlled using a prosthesis and causes no functional deficit.

Fig. 3 Case 3. a, b Facial asymmetry and dystopia of the left eye after a high left-sided maxillectomy. Note the absence of malar projection and lack of support for the nose. c, d After reconstruction with a horizontally placed vascularized split inner cortex flap with internal oblique muscle the patient has a good facial contour and an improvement in mastication and speech

Case 4

In November 1999 a high left-sided maxillectomy was performed for a moderately differentiated squamous cell carcinoma in a 65-year-old man. The resection was performed by the Ferguson- Weber approach and included the orbital floor and the left hemi- palate (class 3a). The defect was covered by a split skin graft, and no support was given to the orbital contents. Postoperatively the patient received radiotherapy. In March 2001 a reconstructive procedure was performed. At the time of admission the patient presented with a significant facial asymmetry with dystopia and enophthalmos of the left eye. He was fed through a percutaneous endoscopic gastronomy tube. A vascularized split inner cortex iliac crest flap with internal oblique muscle based on the deep circumflex iliac artery was raised. The bone was fixed in a horizontal position with a reconstruction plate and screws to the nasal bone and the stump of the zygomatic arch. To create more caudal bony projection for future implants, an additional nonvascularized bone graft was fixed to the convex side of the flap, centered over the dentition of the mandible. Through a separate submandibular incision the ipsilateral facial vessels were dissected. The vascular pedicle was tunneled submucosally to this incision and anastomosed to the facial artery and vein. The postoperative results were good, with improvement in the facial contour and speech, and correction of the eye dystopia and enophthalmos. The percutaneous endoscopic gastronomy tube was removed after 2 weeks, and the patient had sufficient oral intake.

Discussion

In cases in which maxillectomy includes the orbital floor, but the orbital contents are preserved (class 3 maxillectomy defect), vertical dystopia and diplopia are bound to develop. The primary goal is the restoration of the orbital floor, the orbital rim, and the zygomatic arch, thus preserving the function of the eye and bringing back facial symmetry. The challenging reconstruction of the palate is the second goal since its restoration improves mastication and speech. Reconstruction with soft tissues (muscle flap only) provides good lining but fails to offer enough support for the orbital contents and distorts the contour of the face because of sagging. Therefore, especially when a large defect is involved, an osseocutaneous or myo-osseous flap is the first choice. Several flaps have been described over the years. Some good results were obtained using a combination of nonvascularized bone grafts and a soft tissue free flap or pedicled flap(4, 5). The use of nonvascularized bone has a greater risk of resorption and infection, particularly if the patient has had or will receive postoperative radiation therapy(3). Vascularized calvarial bone has been used for maxillary reconstruction and has several advantages(6, 9). The bone can be used as a pedicled graft, it has the right curvature and an inconspicuous donor scar. However, only small defects can be filled, the reconstruction of the deeper part of the orbital floor is limited, and the bone is too narrow for the placement of osseointegrated implants[9, 12]. The chimeric flap was described by Koshima et al.[8], combining an anterolateral thigh flap with a vascularized iliac bone graft using the lateral circumflex femoral system. Although the flap offers many possibilities for reconstruction of midfacial defects, it is a very complicated and time consuming method. The radial forearm flap can also be used as a vascularized bone flap, but is appropriate only in smaller defects[5, 7, 10, 12]. The scapular flap[12, 15, 17, 18] can be elevated as a V-shaped unit providing vascularized bone for both the orbital floor and the maxillary components of the defect, but a major disadvantage is that the patient must be repositioned during the operation. The fibula osteocutaneous free flap[7, 11, 12] is a useful alternative for reconstructing a maxillectomy defect, but does not have enough bony surface to give sufficient support to the orbital contents, and misses the curvature of the calvarial and the iliac bone. The iliac crest flap with internal oblique muscle offers a reliable method for the reconstruction of high maxillectomy defects. The positions of donor and recipient sites allow a two team approach. Harvesting the inner table only is technically easy and preserves the continuity of the iliac crest, reducing donor side morbidity[14]. Shenaq et al.[13] used this flap in combination with split rib grafts, with good results in three cases of complex cranial defects, but otherwise than in our cases they used a full thickness iliac crest graft. Brown et al.[1] used the iliac crest graft with internal oblique muscle, placed vertically in a high maxillectomy defect with orbital exenteration (class 4). In this position the bone is replacing the maxillary buttress, the anterior maxillary wall and antrum, and the orbital rim but not the orbital floor. Thus, when the orbit is retained (class 3), an additional free graft must be inserted to replace the orbital floor to prevent ocular problems. Also, with this method it is difficult to reconstruct the concave contour of the bony midface just under the orbital rim. The split inner cortex iliac crest flap with internal oblique muscle, placed in an horizontal position, is well suited to replace the orbital floor and rim. The natural curvature of the iliac crest resembles the curvature of the orbital rim and zygomatic arch. The muscle can be used to reconstruct the mucosal lining of oral and nasal cavity. Quick epithelialization (2-3 weeks) achieves a rapid healing. The muscle flap provides a well vascularized cover for the bone, especially if additional nonvascularized bone is used. Being thin and pliable, the internal oblique muscle flap can be easily folded allowing the obliteration of the oronasal communication. An overlap with palatal mucosa is needed to prevent recurrence of the oronasal fistula, induced by muscle retraction and atrophy. The overall result in our patients was good. Although in three patients the reconstruction was performed in preirradiated areas, no major complication was recorded. All patients have a good quality of life and have returned to their normal social activities. In our last patient we provided more caudal projection of the bone by fixing additional nonvascularized bone pieces to the convex side of the flap in order to facilitate future dental implants.

Conclusion

The use of a vascularized iliac crest graft based on the deep circumflex iliac artery with internal oblique muscle is a reliable method to reconstruct the orbital floor and rim in a high maxillectomy defect. The flap is easy to harvest and the donor site morbidity is minimized by using only the inner table of the iliac crest(14). By further refining this reconstruction we hope to prevent recurrence of the oronasal fistula and to facilitate the use of dental implants in the future.

References

1. *Brown JS (1996) Deep circumflex iliac artery free flap with internal oblique muscle as a new method of immediate reconstruction of maxillectomy defect. Head Neck 18:412–421*

2. *Brown JS, Rogers SN, McNally DN, Boyle M (2000) A modified classification for the maxillectomy defect. Head Neck 22:17–26*

3. *Coleman JJ III (1994) Osseous reconstruction of the midface and orbits. Clin Plast Surg 21:113–124*

4. *Cordeiro PG, Santamaria E, Kraus DH, Strong EW, Shah JP (1998) Reconstruction of total maxillectomy defects with preservation of the orbital contents. Plast Reconstr Surg 102:1874–1884*

5. *Earley MJ (1989) Primary maxillary reconstruction after cancer excision. Br J Plast Surg 42:628–637*

6. *Ewers R (1988) Reconstruction of the maxilla with a double musculoperiosteal flap in connection with a composite calvarial bone graft. Plast Reconstr Surg 81:431–436*

7. *Foster RD, Anthony JP, Singer MI, Kaplan MJ, Pogrel MA, Mathes SJ (1997) Reconstruction of complex midfacial defects. Plast Reconstr Surg 99:1555–1565*

8. *Koshima I, Yamamoto H, Hosoda M, Moriguchi T, Orita Y, Nagayama H (1993) Free combined composite flaps using the lateral circumflex femoral system for repair of massive defects of the head and neck regions: an introduction to the chimeric flap principle. Plast Reconstr Surg 92:411–420*

9. *Lee HB, Hong JP, Kim KT, Chung YK, Tark KC, Bong JP (1999) Orbital floor and infraorbital rim reconstruction after total maxillectomy using a vascularized calvarial bone flap. Plast Reconstr Surg 104:646–653*

10. McLoughlin PM, Gilhooly M, Phillips JG (1993) Reconstruction of the infraorbital margin with a composite microvascular free flap. Br J Oral Maxillofac Surg 31:227–229

11. Nakayama B, Matsuura H, Hasegawa Y, Ishihara O, Hasegawa H, Torii S (1994) New reconstruction for total maxillectomy defect with a fibula osteocutaneous free flap. Br J Plast Surg 47:247–249

12. Schusterman MA, Reece GP, Miller MJ (1993) Osseous free flaps for orbit and midface reconstruction. Am J Surg 166:341–345

13. Shenaq SM (1988) Reconstruction of complex cranial and craniofacial defects utilizing iliac crest-internal oblique microsurgical free flap. Microsurgery 9:154–158

14. Shenaq SM, Klebuc MJ (1994) Refinements in the iliac crest microsurgical free flap for oromandibular reconstruction. Microsurgery 15:825–830

15. Swartz WM, Banis JC, Newton ED, Ramasastry SS, Jones NF, Acland R (1986) The osteocutaneous scapular flap for mandibular and maxillary reconstruction. Plast Reconstr Surg 77:530–545

16. Taylor GI, Townsend P, Corlett R (1979) Superiority of the deep circumflex iliac vessels as the supply for free groin flaps. Plast Reconstr Surg 64:595–604

17. Wells MD, Luce EA (1995) Reconstruction of midfacial defects after surgical resection of malignancies. Clin Plast Surg 22:79–89

18. Yamamoto Y, Minakawa H, Kawashima K, Furukawa H, Sugihara T, Nohira K (1998) Role of buttress reconstruction in zygomaticomaxillary skeletal defects. Plast Reconstr Surg 101:943–950

8

A comparison between fibula and iliac crest in mandibular reconstruction

8 A comparison between fibula and iliac crest in mandibular reconstruction

Henri A. H. Winters, Dorothea K. G. van Loenen

Abstract

Nowadays the vascularized free fibula flap and the free iliac crest flap are the methods most frequently used to reconstruct the mandible. This is also the case in our clinic. A retrospective nonrandomized study was performed to compare both flaps. The vascularized fibula free flap and the iliac crest free flap were compared in terms of logistics, flap failure, revisionary surgery, donor site morbidity, and recipient site morbidity. No significant differences in flap failure and revision surgery were found between the fibula group and the iliac crest group. Recipient site and donor site complications (major and minor) were significantly less in the fibula group compared to the iliac crest group. In mandibular reconstruction, the free vascularized fibula flap appears to be superior to the free vascularized iliac crest flap in terms of both recipient site and donor site morbidity.

Introduction

Nowadays, the vascularized free fibula flap and the free iliac crest flap are the methods used most frequently to reconstruct the mandible. In the literature, the fibula appears to be the donor site of first choice[1, 2]. However, few comparative studies could be found[3–5]. In our clinic, both flaps are used for reconstruction of the mandible. Before 1996, the iliac crest flap was our flap of choice for this procedure. As a result of our own clinical observations and literature trend, we changed from iliac crest to fibula as the flap of first choice. There was no significant change in our patient population before and after 1996; therefore, it was decided to conduct a retrospective, nonrandomized study to compare both flaps and to determine if our change in policy was correct.

Materials and methods

In the study, the vascularized fibula free flap was compared with the iliac crest free flap in terms of logistics, flap failure, revisionary surgery, donor site morbidity, and recipient site morbidity. Between August 1993 and April 1999, 72 patients underwent mandibular reconstruction using free fibula and free iliac crest flaps. The senior author performed the operation on all patients. Sixty-five patients were reconstructed after tumor resections, while seven patients underwent reconstruction after the resection of benign tumors or trauma. In 45 patients, a fibula was used while in 27 patients iliac crest was chosen. Thirtyeight patients were men, thirty-four women. The mean age was 54 years (range 11 to 80). We could find no significant difference in indication, type of resection, tumor stage, radiotherapy, social status, age, gender, and concurrent disease between our two groups.

Surgical technique

For elevation of the fibula free flaps, a standard method was used with two variations:

1. *When musculocutaneous perforators were present, they were all dissected out off the soleus muscle instead of using a blind muscle cuff.*
2. *No tourniquet was to diminish edema and facilitate primary closure[6].*

Dissection of the iliac crest flaps was preformed with an emphasis on the reduction of donor site morbidity[7]. In all patients the anterior superior iliac spine (ASIS) was preserved and when a mesh was used to reinforce the abdominal wall, it was placed preperitoneally.

Results

Flap failure

Flap failure occurred in three patients (4.2%): two in the iliac crest group (7.4%) and one in the fibula group (2.2%). In one patient in the iliac crest group, the recipient site was closed primarily without the use of the internal oblique muscle. An intra-oral dehiscence developed, causing uncontrollable osteitis, which led to complete flap loss after 6 months. The second flap loss in the iliac crest group occurred after 2 weeks while the patient was treated in an intensive care unit for sepsis. The flap loss in the fibula group was due to thrombosis of the pedicle despite revision surgery on day 1. Partial necrosis of the most distal bony section of a multiply osteotomized iliac crest occurred in one patient (1.4%).

Revision Surgery

Revision of one or two anastomoses was necessary in eight patients (11.1%). Three revisions were preformed in the iliac crest group (11.1%) and five in the fibular group (11.1%). Seven out of these eight flaps survived completely after revision surgery. One flap failed.

Recipient site morbidity

Thirteen patients (18.1%), ten in the iliac crest group (37.0%) and three in the fibula group (6.7%), required additional surgery because of recipient site morbidity, i.e., infections, abscesses, dehiscences, and fistulas. In this group, seven patients,six in the iliac crest group (22.2%) and one in the fibula group (2.2%), developed intra-oral dehiscence or orocutaneous fistula.

Donor site morbidity

In the iliac crest group, 14 (51.9%) donor sites were closed primarily, while in 13 patients, the donor site was closed using mesh (48.2%). Two kinds of mesh were used: a Vicryl® mesh in nine patients and a Marlex® mesh in four patients. In the fibula group, the donor site was closed primarily in 44 (97.8%) patients. In one (2.2%) patient, a split skin graft was used to close the defect. A total of ten major donor site complications were seen in seven patients (9.7%). All major complications occurred in the iliac crest group (25.9%). Remarkably, all of these complications occurred in those patients in whom the donor defect was closed using a Vicryl® mesh. One patient had a burst abdomen, which was operated on. Postoperatively this patient developed a hernia cicatricalis. Another patient had a fracture of the ASIS with an incarcerated hernia; for this complication, part of the ileum had to be resected. The third patient developed an ileus, which was based on an incarcerated hernia of the ileum. The fourth and fifth patient had a hernia cicatricalis. In the sixth patient, the donor site became infected, leading to wound dehiscence. The defect was closed secondarily with a split skin graft. The seventh patient had a femoral nerve neuropathy. Apart from these major donor site complications, which needed short-term medical treatment, 23 patients (31.9%) had one or more minor donor site complications, which persisted after 3 months. Twenty-two patients in the iliac crest group (81.5%) complained of abdominal bulging/ contour deformity, mild pain/discomfort, and/or minor gait disturbance. One patient in the fibula group (2.2%) complained of persistent pain during and after walking.

Discussion

Comparison between two different flaps is always difficult. A small difference in indication or patient selection may lead to significant differences between groups. Our study is retrospective and not randomized, but our groups are similar in all aspects, and all operations were performed by the same surgeon. Therefore, we feel that the results of our study are still valuable. Several aspects of the differences in the two flaps are difficult to compare. There are differences in bone quality, size and shape, the fibula being stronger and longer, and the iliac crest having the better height for reconstruction of the dentate mandible. Both take osseo-integrated implants well[1, 8–11]. Though there is discussion about these aspects and these factors may make all the difference in choosing the best flap for each individual patient, we have not taken them into consideration because it was impossible for us to quantify the differences in the functional outcome. The same goes for the cosmetic aspect of the donor site. The scar of the iliac crest flap donor site is inconspicuous, but abdominal bulging and contour deformity may lead to complaints, while the longitudinal scar of the fibula flap donor site is clearly visible under shorts or skirt but

appeared to be well-accepted by our patients. The logistics of the operation can also be an important factor in flap choice; in both flaps ablative surgery and flap elevation can be performed simultaneously, although this being easier in the fibula flap. The differences in outcome between the two groups are shown in Table 1. There is no difference in the amount of revision surgery. This is probably due to the fact that all operations were performed by the same surgeon, resulting in the same quality of anastomosis. Eleven percent of revision surgery may seem on the high side, but this can be greatly contributed to by a very liberal attitude toward surgical re-intervention in a period where not every member of the medical and nursing staff was equally experienced in monitoring free flaps. Whenever there was doubt about the viability of a flap, the anastomoses were checked in the operating room. Of the eight revisions, five turned out to be false alarms; the neck could be closed without performing any vascular re-anastomosis. We feel that flap loss in the iliac crest group was greatly influenced by secondary complications, specifically infections. The higher recipient site morbidity may be of influence in this. However, the groups are too small for us to come to conclusions on this aspect. Recipient site morbidity was significantly higher in the iliac crest group, especially wound dehiscence and fistula formation. In reconstructions where the iliac crest flap was used, the internal oblique muscle was used for the reconstruction of intra-oral defects, whereas the fibula flap offers a thin pliable skin paddle for the same purpose. Watertight closure is of utmost importance in the reconstruction of intra-oral defects. Leakage of saliva will often cause an infection, which can lead to flap loss or formation of an orocutaneous fistula. We feel that the joint between the muscle and the mucosa is susceptible to leakage of saliva. This improves when a 2-cm overlap of mucosa is created on the muscle, but still remains more vulnerable than a skin–mucosa joint. The higher rate of recipient site complications compares well with the study of Shpitzer et al.[4], where similar differences are found. In some patients where the skin paddle of the iliac crest flap is very thin, this can be used for intra-oral reconstruction and may lead to less recipient site complications.
In general, the skin paddle of the iliac crest flap is considered to be too bulky and stiff for intra-oral use. In all our patients, intra-oral reconstructions were performed using the internal oblique abdominal muscle without a skin graft.
In this study, the most striking difference is found in the donor site morbidity. Whereas in the fibula group, no complications were found after 3 months with the exception of one patient complaining of mild discomfort when walking.
In the iliac crest group, only the patients where an inner table iliac crest flap without the internal oblique abdominal muscle had been used were completely free of complications. Minor complications occurred in majority of patients in the iliac crest group (81.5%) and major complications in 26%. To avoid herniation, a mesh was used in all patients where the internal oblique muscle was included in the flap. Initially we used Vicryl® mesh, but we later changed this to Marlex® mesh.

All major complications occurred in the patients in whom Vicryl® was used, which was the main reason for changing the technique. The amount of major complications in the iliac crest flap may therefore be less dramatic than our table suggests, but only if the donor site is closed with the utmost care[5]. Minor complications such as mild discomfort, minor contour deformity without herniation, and minor gait disturbance are present in the majority of patients, despite a careful operating technique. Although these minor complications appear to be of lesser importance, they generally cannot be corrected and are often troublesome to the patient, albeit not to the extent that they interfere with daily life. Our findings again confirm the conclusions of Shpitzer et al.[4], but may seem to contradict the results of Rogers et al.[5], partially due to our lower morbidity in the fibula flap group but also to a higher donor site morbidity in the iliac crest group. The major donor site complications in the iliac crest flap seem to be related to adequate closure of the abdominal wall and the absence of one of the three oblique abdominal muscles. As Rogers et al.[5] state, they preferred to use the iliac crest when a relatively small soft tissue defect was present. This will probably mean that the soft tissue defect at the donor site will also have to be smaller. This can make a major difference in donor site complications. Also the minor donor site complications we have found in the majority of our patients in the iliac crest group mostly did not interfere with their daily life and might not lead to big differences in quality of life tests. Although we feel that the initial problems we had in our iliac crest group may bias the end result in favor of the fibula flap in terms of donor site morbidity, there are enough significant differences in both recipient site and donor site morbidity to confirm the conclusions of Shpitzer et al.[4] and to justify the worldwide tendency to use the fibula flap as first choice for mandibular reconstruction. In our opinion, this by no means indicates that the iliac crest

Table 1 *Differences in outcome between the fibula and the iliac crest groups*

	Iliac crest (27)	Fibula (45)	Total (72)
Flap failure	2 (7.4%)	1 (2.2%)	3 (4.2%)
Revision surgery	3 (11.1%)	5 (11.1%)	8 (11.1%)
Recipient site morbidity (total)	10 (37.0%)	3 (6.7%)	13 (18.1%)*
Fistula/dehiscence	6 (22.2%)	1 (2.2%)	7 (9.7%)*
Major donor site morbidity	7 (25.9%)	0 (0%) 7	(9.7%)*
Minor donor site morbidity	22 (81.5%)	1 (2.2%) 23	(31.9%)*

** Significant according to chi-square test and the Fisher exact test* flap is obsolete. It is a valuable flap that will still be a definitive first choice for some patients, while being a good second choice in most other cases.

Conclusion

The clear differences in both recipient site and donor site morbidity between the fibula and iliac crest flaps justify the worldwide tendency to use the fibula flap as first choice for mandibular reconstruction.

References

1. *Celebioglu S, Unlu RE, Kocer U et al (1998) Reconstruction of mandible with fibula free flap. Microsurgery 18:156–159*

2. *Cheung SW, Anthony JP, Singer MI (1994) Restoration of anterior mandible with the free fibula osseocutaneous flap. Laryngoscope 104:105–113*

3. *Haughey BH, Fredrickson JM, Lerrick AJ et al (1994) Fibular and iliac crest osteomuscular free flap reconstruction of the oral cavity. Laryngoscope 104:1305–1313*

4. *Shpitzer T, Neligan PC, Gullane PJ et al (1999) The free iliac crest and f ibula flaps in vascularized oromandibular reconstruction: comparison and long-term evaluation. Head Neck 21 (7):639–647*

5. *Rogers SN, Lakshmiah SR, Narayan B et al (2003) A comparison of the long-term morbidity following deep circumflex iliac and fibula free flaps for reconstruction following head and neck cancer. Plast Reconstr Surg 112 (6):1517–1525*

6. *Winters HAH, Jongh de GJ (1999) Reliability of the proximal skin paddle of the osteocutaneous free fibula flap. Plast Reconstr Surg 103(3):846–849*

7. *Winters HAH, Smeele LE (1999) Reduction of donor site morbidity of the iliac crest free flap by preservation of the anterior superior iliac spine. Eur J Plast Surg 23:183–184*

8. *Chen ZW, Yan W (1983) The study and clinical application of the osteocutaneous flap of fibula. Microsurgery 4:11–16*

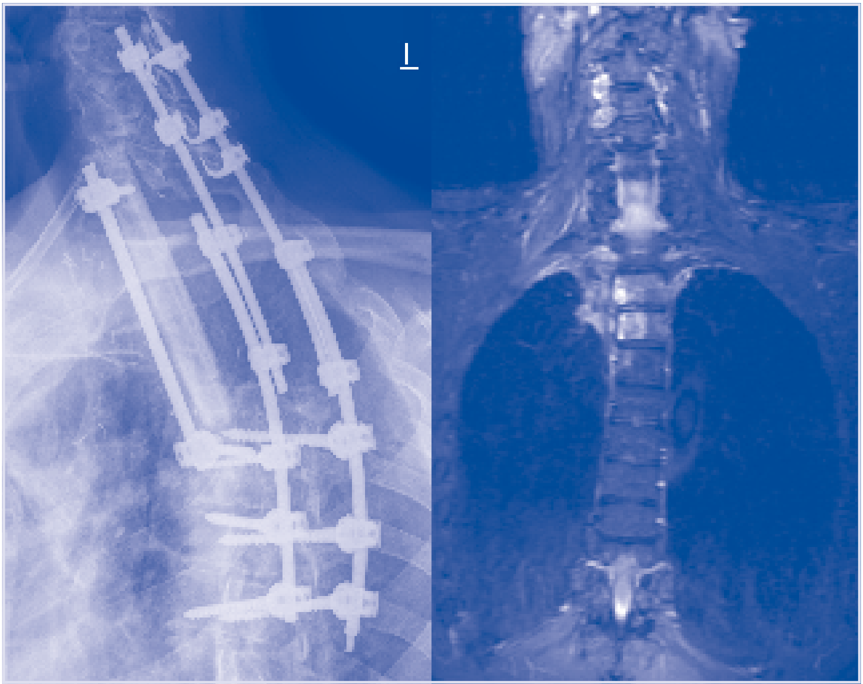
9. *Hildalgo DA (1989) Fibula free flap: a new method of mandible reconstruction. Plast Reconstr Surg 84:71–79*

10. *Boyd JB (1994) The place of the iliac crest in vascularized oromandibular reconstruction. Microsurgery 15:250–256*

11. *Seikaly H, Chau J, Li F, Driscoll B, Seikaly D, Calhoun J, Calhoun KH (2003) Bone that best matches the properties of the mandible. J Otolaryngol 32(4):262–265 208 Eur J Plast Surg (2007) 29:205–208*

9

The use of free vascularized bone grafts in spinal reconstruction



9 The use of free vascularized bone grafts in spinal reconstruction

H.A.H. Winters, A.A. van Engeland, P.I.J.M. Wuisman

Abstract

The use of vascularized bone has proven its value in reconstructive surgery. Reconstruction of defects in the long bones has been described frequently, whereas the reconstruction of spinal defects or instability with free vascularized bone grafts is not a common technique at this moment. The reconstructive surgeon that faces a spinal reconstruction has to decide which flap to take, how to approach the defect and where to find adequate acceptor vessels. Based on our experience in 23 cases, we describe the use of free fibula and iliac crest flaps in spinal surgery from the reconstructive surgeons point of view. In one of these cases we failed to vascularize the bone graft for lack of acceptor vessels, in the remaining 22 cases, revascularization was successful.

The initial disease will greatly dictate the extend of the final defect and at least part of the approach, especially when a malignant tumor has to be removed. Generally dorsal instrumentation will also be required to provide the initial stability for the reconstruction. This will mostly be done through a dorsal approach. In rare cases it will be possible to do the resection, reconstruction and stabilization through the same dorsal approach. In these cases the acceptor vessels will also have to be dissected through this approach. More frequently an additional lateral or ventral approach is used to finish the ablative resection and to reconstruct the defect. In these cases the acceptor vessels are dissected through this approach as well. Special attention is paid to the dissection and use of acceptorvessels for lumbar, thoracic and cervical reconstructions. Tricks and pitfalls are discussed for anterior, dorsal, thoracolumbar, lumbar and trans-sternal approaches.

This multi-disciplinary team work can only succeed through careful planning.

Introduction

Nowadays the use of free vascularized bone grafts is a well accepted method in the reconstruction of larger skeletal defects, including disorders of the spine. The advantages of vascularized bone over non vascularized bone are well known and include rapid consolidation, resistance against infection, hypertrophy reaction guided by mechanical load and tolerance of therapeutic levels of radiation.[1,2,3,4] Indications concerning the spine include progressive symptomatic spinal deformities, trauma, (chronic) infections or malignancies, which can be primary or metastatic5. These disorders can cause local changes in structural integrity, leading to collapse, or demand an en bloc

resection of one or more vertebrae. Bone grafts are used - often combined with instrumentation - to achieve correction, stabilization and fusion. When a non-vascularized bone graft is used, this will be incorporated by creeping substitution, a process which may take many months and involves resorption of the graft followed by gradual replacement, resulting in less strength and delay in integration.[2,6]
A non-vacularised bone graft is also more prone to infection. When using a free vascularized bone transfer, the blood supply of the bone is preserved, allowing the osteogenic cells to survive after transplantation[7]. This will improve mechanical properties and the time necessary for fusion, hence the period of immobilisation[8,9].
Judged by the scarcity of literature on this subject, reconstruction of the spine using vascularized bone grafts is still rarely performed. Due to the advantages of this method, the demand may increase in the near future.
For the reconstructive surgeon, this field of surgery brings new challenges concerning choice of flap, planning of the operative procedure, technique of inserting and securing the flap, selection of acceptor vessels and monitoring. These subjects are discussed based on the experience with 23 patients over a period of ten years.
Reconstruction of the spine using vascularized bone grafts can only be performed in a multidisciplinary setting. Neurosurgery, orthopaedic surgery, traumatology, vascular surgery, thoracic surgery and plastic & reconstructive surgery are the involved disciplines in these operations. At least as important as the operating specialists are the theatre staff, the anaestheologist and the ICU specialist. This group of different specialists should communicate about the various points of view and interests, so everyone knows what is expected of him/her and things will work smoothly during the operation. To obtain this we strongly advocate to put the operation on paper in a step by step fashion and arrange a pre-operative meeting of all involved, including the theatre staff.

Materials and Methods

Over a period of 10 years (1994-2004) we used vascularized bone grafts for spinal reconstruction in 23 patients. 11 patients were male and 12 female. The mean age was 36 years, ranging from 4 to 70 years. In 7 cases stabilisation of a progressive spinal deformity was performed and in 16 cases segmental reconstruction of the spine was performed after resection of spinal or paraspinal malignant tumors *(fig. 1&2)*. In two patients a free vascularized iliac crest flap was used, in all other patients reconstution was performed with free fibular grafts. In one patient of the fibula group, revascularization was impossible due to lack of acceptor vessels (pat nr. 14). In this patient the fibula finally was used as an unvascularized graft. The remaining 20 fibula's were all successfully revascularized. Indications and patient data are shown in table 1.

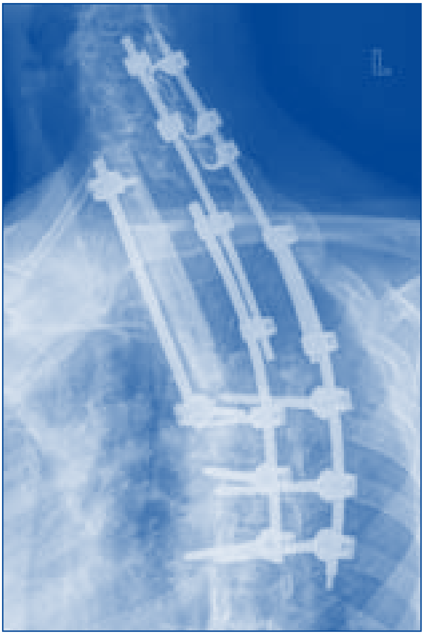


fig 1, patient nr. 19; malignant tumour with spinal involvement

fig 2, same patient after resection and reconstruction with double barrel vascularized fibula

Table 1

Pat. Nr.	M/F	Age	Bone graft	Defect	Osteotomies	arterial anastomosis	venous anastomosis
1	M	31	Fibula	T2-T8	double barrel	e-t-e: intercostal a	e-t-s: thoracic duct
2	F	49	Fibula	T12-L4	single strut	e-t-e: intercostal a	e-t-e: hemi azygos v
3	F	23	Fibula	T11	quadruple barrel	e-t-e: intercostal a	e-t-e: intercostal v
4	F	45	Fibula	T7-T9	double barrel	e-t-e: intercostal a	e-t-e: intercostal v
5	M	19	Fibula	T8-T12	double barrel	e-t-e: intercostal a	e-t-e: intercostal v
6	F	4	Fibula	T10	double barrel	e-t-e: intercostal a	e-t-s: thoracic duct
7	F	51	Iliac crest	T6-T8	single piece	e-t-s: aorta	e-t-e: unidentified v
8	F	69	Iliac crest	T2-T5	single piece	e-t-e: intercostal a	e-t-e: intercostal v
9	M	14	Fibula	C1-C6	single strut	sup thyroid a	int jugular v
10	F	24	Fibula	C4-T1	single strut	sup thyroid a	int jugular v
11	F	33	Fibula	T12-L5	triple barrel	e-t-e: lumbal a	e-t-e: lumbal v
12	M	46	Fibula	L5-L4	double barrel	e-t-s: comm iliac a	e-t-s: iliac v
13	F	22	Fibula	T9-L2	single strut	e-t-e: intercostal a	e-t-e: hemi azygos v
14	M	36	Fibula	os sacrum	single strut	unvascularized	unvascularized
15	M	57	Fibula	T2-T4	double barrel	e-t-e: int thoracic a	e-t-e: int thoracic v
16	F	53	Fibula	T12-L5	double barrel	e-t-e: lumbar a	e-t-e: lumbar v
17	M	58	Fibula	C3-T2	double barrel	e-t-e: int thoracic a	e-t-s: jugular v
18	M	70	Fibula	os ileum	double barrel	e-t-e: sup gluteal a	e-t-e: sup gluteal v
19	M	46	Fibula	T1-T5	double barrel	e-t-e: int thoracic a	e-t-e: int thoracic v
20	M	7	Fibula	C4-C6	single strut	e-t-e: facial a	e-t-e: branch int jug v
21	F	43	Fibula	T9-L1	double barrel	e-t-s: aortic graft	e-t-e: hemi azygos v
22	F	8	Fibula	T1-T3	single strut	e-t-e: int thoracic a	e-t-e: int thoracic v
23	M	13	Fibula	L4	quadruple barrel	e-t-s: inf mesenteric a	e-t-s: inf mesenteric v

Technical considerations

Flap choice

Several donorsites are available for harvesting a free vascularized bone graft. The choice of bone graft will depend on type, size, shape and location of the defect as well as the mechanical load placed on the reconstruction. The fibula, iliac crest, radial forearm, scapula and rib are the most important donorsites used for transplantation. For spinal reconstruction a substantial volume and/or length of bone is needed in most cases. Also high compression strength is desired. Further considerations are the possibility to simultaneously raise the flap in a two team approach and the wish to minimize donorsite morbidity. The fibula is superior in axial strength[10,11], provides up to 30 cm of bone (in the adult male)[7], is easy accessible in prone, supine and lateral position, and has low donorsite morbidity[12,13,14]. This makes the fibula our flap of choice, the iliac crest being a good second.

Planning and logistics

In most cases of spinal reconstruction, additional instrumentation is mandatory to provide initial stability. In segmental reconstruction, often both dorsal and ventral instrumentation is needed. This calls for two different approaches, necessitating the patient to be turned. Our preference is to start with the dorsal approach, doing the necessary ablative dissection -especially when a segmental resection is performed- and inserting the instrumentation needed for stability. This operation is completely finished and the patient is taken to the ICU ward. The following day, the operation is continued in supine or lateral position. No further repositioning is required. The reconstructive surgeon participates in the ablative dissection to the extend that the acceptor vessels are selected and dissected as early in the operation as possible. These are then guarded throughout the remaining operation. After this, the reconstructive surgeon can raise the free vascularized bone flap, while the colleagues from traumatology/neurosurgery/orthopaedic surgery continue their work on the acceptor site.

Patients that undergo spinal surgery are widely exposed, blood loss is often extensive and the operation is of long duration. They are susceptible to hypothermia and poor peripheral circulation. There is an increased risk of deep venous thrombosis[15,16]. We found venous thrombosis in the deep peroneal veins of the already raised fibula flap in three patients[3/23]. In all these three patients there had been an extensive period of time (3-8hrs) between the dissection of the fibula flap and the actual transfer, leaving the flap attached to the lower leg by its vascular pedicle only. In all three patients thrombectomy was performed upon transfer and no further problems were seen after re-vascularization. We feel it is advisable to leave the donor leg covered and warm for as long as possible, raising the flap as close to the moment of actual transfer as possible, covering and warming the donor leg immediately after closure of the donor site.

Often ventral instrumentation is used to stabilize the spine. This should be placed and fixed after placement of the bone flap, but preferably before the re-vascularization to avoid unnecessary pulling of the anastomosis when manoeuvring the instrumentation. Care should be taken to prevent compression of the vascular pedicle. This will lengthen the ischemic period of the flap, but we consider this to be the lesser risk. The anastomoses are then made, considering the best position of the pedicle.

Acceptor vessels

Free flap surgery has proven to be very successful. Failure rates can be well under 5% in experienced hands[17]. Success however very much depends on the quality of the acceptor vessels. In microsurgical reconstruction of the spine, selection and dissection of acceptor vessels has provided us with new problems and challenges, which will be discussed in this chapter.

In the area of the cervical spine; an anterolateral approach is used to reach the vertebral corporae. This provides us with a choice of possible acceptor vessels; transverse cervical artery; superior thyroid artery and facial artery are suitable in size and location, as well as the deep and superficial jugular veins. Because of the proximity and quality of the acceptor vessels in the cervical area, microsurgical revascularization rarely presents any difficulties.

The thoracic area is the most difficult and challenging area for spinal reconstruction. Selection of acceptor vessels greatly depends on the approach that is chosen, and should be carefully planned ahead. There are three basic approaches; anterior, dorsal and lateral.

The dorsal approach is normally used for partial ablative dissection and instrumentation, followed by a lateral or anterior approach for further ablative surgery and reconstruction, as described under planning above. However, in selected cases, the complete resection and reconstruction can be done through a dorsal approach only. This means that the ablative resection has to be done very carefully, without damaging the spinal cord. Also the bone used for reconstruction has to be taken beyond the spinal cord to its new position in the spinal column and needs to be fixed there. To gain access to the corpus vertebrae, the onset of 2 to 3 ribs has to be removed. At this moment the reconstructive surgeon should be present and dissect and preserve the intercostal vessels of the next rib cranially. Size and quality of these vessels can be inadequate, especially if a long pedicle is needed. The vein can be thin walled and adherent to the rib, making it difficult to dissect. The operating field is located deep in the body, much deeper than most of us would expect, making the whole procedure difficult, tedious and dangerous. We have successfully reconstructed a single corpus vertebrae with a quadruple barrel vascularized fibula via a dorsal approach only (pat nr. 4), but we certainly would not recommend this approach as the standard procedure for thoracic spinal reconstruction.

The lateral approach to the thoracic spine is well known18 and provides a reasonable working space. The desired acceptor vessels are; intercostal artery and azygos or hemi-azygos vein. In these cases too, the reconstructive surgeon should select, dissect and protect his acceptor vessels at the beginning of the resection. In cases of spinal or para-spinal tumors, the azygos and/or hemi-azygos veins can be dislocated or included in the tumor. Therefore they can be difficult to find or have to be included in the resection, leaving the reconstructive surgeon in an awkward situation. In one case we had to use the thoracic duct as venous acceptor because all potential acceptor veins had been damaged in the resection19. In a lateral approach, accessibility of the site of reconstruction is better than in a dorsal approach, but it still is a deep cavity with a narrow opening. It can be difficult for the surgeon to physically reach his target. 21 cm. needle holders and forceps are a great asset in this type of surgery. In some cases we were not able to get the microscope close enough to be able to focus, or the surgeon could not look through the microscope and get his hands at the operating site at the same time. This problem was solved by the use of loupes of a 4.5 x magnification, improving the freedom of movement and the choice of position for the surgeon.

In our view, the best approach of the thoracic vertebrae for reconstructional purposes is the anterior approach. Via a midline sternotomy, the spine is reached through the mediastinum. The distance between sternum and spine is surprisingly short, giving an excellent accessibility. The internal mammary artery and vein provide acceptor vessels of good quality, diameter and length[20,21,22]. They are more easy to find and dissect than the alternatives deep in the thoracic vault, thus making microsurgical re-vascularization far more easy than through lateral or dorsal approaches. Because of the excellent accessibility, both resection and reconstruction are easier and less tiring. We have now used the anterior approach in 4 patients and consider it a major improvement.

The lumbar spine will generally be approached through a retroperitoneal route via a lumbotomy incision. This provides reasonable access. Considering the extensive vascularisation of the pelvic region, one would expect plenty of acceptorvessels to be available. The pelvic vessels however are difficult to reach and dissect through this incision. The most usefull acceptor vessels in this region are the lumbar arteries and veins and, maybe surprisingly, the superior and inferior mesenteric artery and veins. These vessels will be in full view and are very close to the lumbar spine. They can either be used for end to side anastomosis or one of their minor branches can be used for end to end anastomosis. However, care should be taken not to damage or transect the mesenteric arteries and veins themselves or their main branches for the risk of intestinal necrosis. Especially for the lower lumbar spine, there is also the possibility of bringing in a pedicled vascularized iliac crest graft. This can be based on the iliac branches of the iliolumbar artery[23,24]. A lower than usual incision for the lumbotomy is advised in this case. We have performed this operation in one patient. Because a pedicled flap was used and not a free vascularized flap, this patient is not included in this series.

Positioning and fixation

Positioning and fixation of the bonegraft is an issue that also concerns the reconstructive microsurgeon. Whilst the main goal will be to obtain optimal mechanical strength and stability, our main concern will be to avoid compression, coiling, kinking or stretching of the vascular pedicle. When stabilisation needs to be performed for progressive deformity or instability caused by osteoporosis, trauma, neurofibromatosis etc. an axial slot is made in the affected vertebrae. One or two osteotomies of the bone graft may be needed to follow the form of the spine. The bone graft is then positioned press-fit into this slot, keeping the vascular pedicle on the outside, pointing in the direction of the acceptor vessels. As little fixation as possible is used. k-wires are avoided in this situation, as they tend to work loose and can start wandering. Single screw fixation is our preferred method, often using resorbable screws, as the mechanical load on this fixation will be minimal. For segmental reconstruction, a significant amount of bone is needed, the emphasis being on compression strength. We normally use double- and triple-barrel fibula grafts and even have used a quadruple barrel fibula in one case. When osteotomizing and folding the fibula, sometimes a small (< 1cm) segment of fibula is removed to facilitate a smooth bend in the pedicle. A slot is made in the top and bottom plate of the vertebra under and over the defect. The fibula is cut to size, folded and pressed or gently hammered into this slot avoiding damage, compression or kinking of the pedicle. By pointing the vascular pedicle towards the acceptor vessels, on the outside of the most ventral fibular strut, the most ideal position is reached. There is a risk of pushing the most dorsal fibula strut into the spinal cord, resulting in compression. To avoid this, the slot in the top and bottom vertebrae should is not be open on the dorsal side. The position of the strut should be checked by palpation and x-ray before the operation is continued. If a ventral reconstruction plate is used for further stabilisation, axial compression on the fibula strut can be applied. This will firmly fix the strut and no further fixation is needed. In cases that need additional fixation of the fibula struts, single screws are preferred over k-wires. Again care should be taken in positioning the reconstruction plate, to avoid compression of the vascular pedicle. After the ventral instrumentation has been positioned, the anastomosis can be performed.

Monitoring

Free flaps can be monitored best if they have a skin paddle25. Monitoring bone flaps without a skin paddle is difficult, and becomes extremely difficult when these flaps are buried in the center of the body. For reconstructions of the cervical spine, it sometimes is possible to include a small skin paddle that can be sutured into the neck just for the purpose of monitoring, but for reconstructions at thoracic or lumbar level this is absolutely impossible. Although we have performed spect- and pet scans of these patients, they provide nothing but a snapshot in time and can not be used for monitoring. They do not lead to microvascular re-intervention. On the other hand we feel that one can seriously question the justification of any re-intervention in the first days after such major surgery. Most patients have suffered significant blood loss, resulting in reduced hemostatic and chemical stability. The complication risk of putting the patient through an extra operation within the first few days after the initial procedure is likely to be to high.

Results

Due to the lack of monitoring, it is difficult to obtain absolute information about flap survival. Spect and pet scans may give false results and, considering the absence of clinical consequences, we did not want to subject our patients to a selective angiography just to satisfy our curiosity. The clinical and radiological results of – long term – follow up will have to prove the value of this type of reconstruction. Although discussion of the clinical and orthopaedic results is beyond the scope of this paper, we can report that the long term results show consolidation in all cases, even in the unvascularized one.

Conclusion

We feel that the possibility of using vascularised bone is a valuable addition to spinal surgery, enabling the operation of difficult cases. Careful planning and a multidisciplinary approach are the keys to success in these cases.

References

1. *Minami A, Kasashima T, Iwasaki N, Kato H, Kaneda K. Vascularised fibular grafts. An experience of 102 patients. J Bone Joint Surg Br. 2000; 82(7) : 1022-5.*

2. *Tamai S. Experimental vascularized bone transplantations. Microsurgery 1995;16(4) :179-85.*

3. *Wright N, Kaufman B, Haughey B, Lauryssen C. Complex cervical spine neoplastic disease: reconstruction after surgery by using a vascularized fibular strut graft. Case report. J Neurosurg 1999; 1 Suppl:133-7.*

4. *Kim C, Abrams R, Lee G, Hoyt D, Garfin S. Use of vascularized fibular grafts as a salvage procedure for previous failed spinal arthrodesis. Spine 2001; 26(19): 2171-5.*

5. *Lee MJ, Ondra SL, Minedea SA, Fine NA, Dumanian GA. Indications and rationale for use of vascularized fibula bone flaps in cervical spine arthrodeses. Plast Reconstr Surg 2005; 116(1):1-7.*

6 *Dell PC, Burchardt H, Glowczewskie FP Jr. Aroentgenographic, biomechanical, and histological evaluation of vascularized and non-vascularized segmental fibular canine autografts. J Bone Joint Surg Am 1985; 67(1):105-12*

7 *Moran CG, Wood MB. Vascularized bone autografts. Orthop Rev 1993; 22(2):187-97.*

8 *Shaffer JW, Field GA, Goldburg VM, Davy DT, Fate of vascularized and non vascularized autograft. Clin Orthop 1985; 179: 32-43.*

9 *Goisain AK, Song L, Santoro TD, Amarante MT, Simmons DJ. Long-term remodelling of vascularized and nonvascularized onlay bone grafts: a macroscopic and microscopic analysis. Plast Reconstr Surg 1999; 103(5):1443-50.*

10 *Smith MD, Cody DD. Load-bearing capacity of corticocancellous bone grafts in spine. J Bone Joint Surg Am 1993; 75(8):1206-13*

11 *Rao S, McKellop H, Chao D, Schildhauer TA, Gendler E, Moore TM. Biomechanical comparison of bone graft used in anterior spinal reconstruction. Freeze dried deminaralized femoral segments versus fresh fibular segments and tricortical iliac blocks in autopsy specimens. Clin Orthop Relat Res 1993; (289):131-5.*

12 *Garrett A, DucicY, Athre RS, Motley T, Carpenter B. Evaluation of fibula free flap donor site morbidity. Am J Otolaryngol 2006; 27(1):29-32.*

13 *Rogers SN, Lakshmiah SR, Narayan B, Lowe D, Brownson P, Brown JS, Vaughan ED. A comparison of long-term morbidity following deep circumflex iliac and fibula free flap for reconstruction following head and neck cancer. Plast Reconstr Surg. 2003;112(6):1517-25; discussion: 1526-7.*

14 *Klein S, Hage JJ, Woerdeman LA. Donor-site necrosis following fibula free-flap transplantation: a report of three cases. Microsurgery 2005; 25(7): 538-42; discussion: 542.*

15 *Lee KS, Han SB, Baek JR. Free vascularized osteocutaneous fibular graft to the tibia in 51 consecutive cases. J Reconstr Microsurg 2004; 20(4):277-84.*

16 *Janowski EM, Mazer N, Barbieri CH, Goncalves RP. The effect of venous occlusion on the integration of vascularized cortical bone graft. J Reconstr Microsurg 1993; 9(3):219-25.*

17 Podrecca S, Salvatori P, Squadrelli Saraceno M, Fallahdar D, Calabrese L, Cantu G, Molinari R. Review of 346 patients with free-flap reconstruction following head and neck surgery for neoplasm. J plast Reconstr Aesthet Surg. 2006; 59(2): 122-9.

18 Wuisman PI, Jiya TU, Van Dijk M, Sugihara S, Van Royen BJ, Winters HA. Free vascularized bone graft in spinal surgery: Indications and outcome in eight cases. Eur Spine J 1999; 8(4): 296-303.

19 Winters HA. The thoracic duct as a venous receptor vessel for free flap transplantation. Plast Reconstr Surg. 1998;101(3): 872-3.

20 Moran SL, Nava G, Benham AH, Serletti JM. Anoutcome analysis comparing the thoracodorsal and internal mammary vessels as recipient sites for microvascular breast reconstruction: a prospective study of 100 patients. Plast Reconst Surg. 2003; 111(6): 1876-87.

21 Lacman S, Satyapal KS, Shi Q, Hayashida N. Morphometry of the internal thoracic arteries. Surg radoil Anat 1998; 20(4): 243-7.

22 Sasajima T, Bhattacharya V, Wu MH, Sauvage LR. Morphology and histology of human and canine internal thoracic arteries. Ann Thorac Surg 1999; 68(1):143-8.

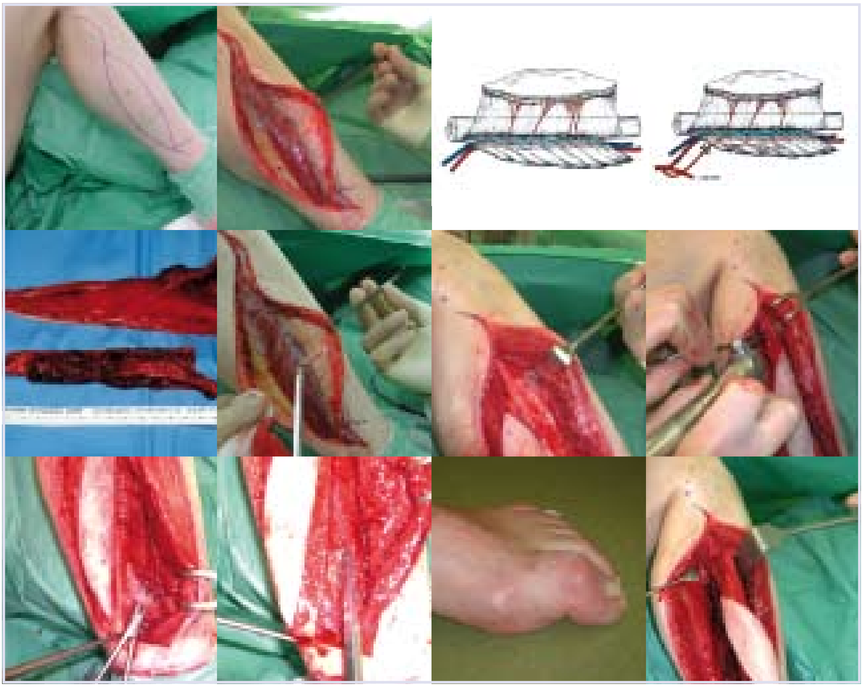
23 Winters HA, Van Harten SM, van Royen BJ. The iliolumbar artery as the nutrient pedicle for an iliac crest graft: a new technique in reconstruction of the lumbar spine. Plast Reconstr Surg 2002; 109(1): 249-52.

24 Winters HA, Smeele LE, Leenmans CR. The bipedicled iliac crest flap. J Reconstr Microsurg 1996; 12(4): 257-9.

25 Imran Y, Zulmi W, Halim AS. Skin paddle as an indicator of the viability of vascularised fibular graft. Singapore Med J 2004; 45(3): 110-2.

10

The osteo-myocutaneous fibula flap; How I do it



10 The osteo-myocutaneous fibula flap; How I do it

Introduction

The fibula flap has become the most popular flap for the reconstruction of major bony defects. These include the long bones in the extremities, the mandible and the spine. The way of dissecting this flap has been described in many books and papers[1,2,3]. Still I've often been asked by colleagues to demonstrate the exact sequence of dissection, including all tricks and pitfalls. The technique described below has been developed in over 150 operations performed by the author.

Pre-operative work up

Although still a point of discussion in literature, we do not routinely perform angiography of the donor leg. In our experience the risk of finding a vascular abnormality that would endanger either the flap or the donorleg is not big enough to justify an angiography for every patient.The patient should have no history of vascular disease. To further assess the circulation in the donor leg, a duplex scan (ultrasound and doppler) is performed and the ankle/arm index is measured. If these are abnormal an other flap is chosen.
Doppler mapping of perforators is often advised. In my opinion this gives relatively little information about the quality of the perforators in the posterolateral septum, so we do not routinely perform doppler mapping. The perforators can easily be inspected and selected when the soleus muscle is freed of the posterolateral septum, about ten minutes into the operation.

Positioning

Depending on the position of the defect, the patient can be in supine (mandible, lower extremity), lateral (spine, humerus) or prone position (spine). When the patient is in supine position, the leg is flexed 90° at the knee and endorotated slightly at the hip. A 2kg sandbag is positioned to support the foot *(fig 1)*. In the lateral position the knee is bent slightly for stability. To make the dissection more easy, the leg should be supported by the upper leg, the knee, the ankle and the foot. The calf should be left hanging free. In the prone position the knee is flexed slightly by placing a foam support under the foot. No tourniquet is used during the dissection. This strongly reduces post operative edema. Therefore most defect can be closed primarily, even when a skin paddle of up to 6 cm wide has been included in the flap. Muscular and musculocutaneous perforators are better seen and dealt with during the dissection, thus reducing blood loss after the revascularization in both flap and donorsite. Also there is no ischaemia in the flap before the actual transfer.

Surgical technique

The skin paddle is designed over the posterolateral septum. Ideally the septum should be 1/3th from the anterior border of the skin paddle, leaving the largest part of the skin paddle on the dorsal side of the septum. The septum does not follow the fibula! It rather forms the dorsal border of the long peroneal muscle. As this muscle crosses the fibula in its lower third, the septum is subsequently positioned more dorsal in this area. The long peroneal muscle can be seen and/or palpated in most patients, helping us to define the position of the septum. Markings are made on the skin 5 cm under the proximal head of the fibula and 8 cm cranial of the lateral malleolus. These markings define the positions of the highest and lowest possible osteotomies The proximal 5 cm of the fibula should be spared to preserve the stability of the knee (insertion of the lateral collateral ligament of the knee and the lateral hamstrings) and the distal 8 cm of the fibula are needed for stability of the ankle (syndesmosis and lateral ligaments of the ankle). In contrast to several descriptions of this operation, I start the dissection from the dorsal side. The skin is incised and the incision is deepened to a subfascia level. The soleus muscle is freed from the fascia and the posterolateral septum comes in to view.

Fig 1

Fig 2

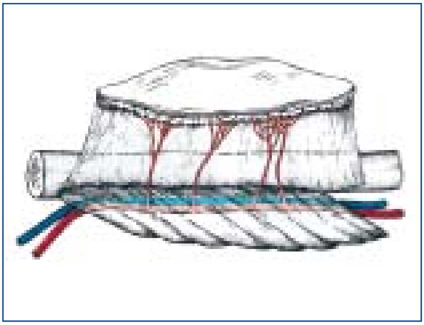


Fig 3

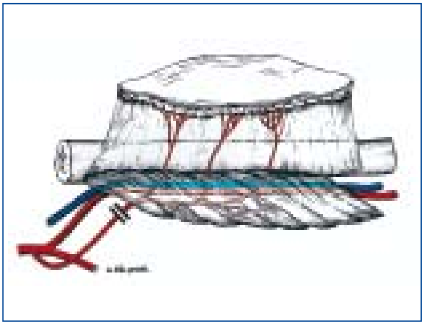


Fig 4

The perforators of the skin paddle are located on this side of the septum and can easily be seen *(fig 2)*. Normally the perforators in the caudal part of the flap will run through the flexor hallucis longus muscle. The perforators in the cranial part of the flap can either run on the septum, perforate the origin of the soleus muscle and go straight into the peroneal vessels*(fig 3)*, or run into the soleus muscle and follow a cephalad course through the muscle, converging with other muscle branches and skin perforators to finally reach the peroneal vessels high in the lower leg *(fig 4)*. They might even run up to the popliteal vessels. When septal perforators or musculoseptal perforators through the flexor hallucis longus muscle are present, The musculocutaneous perforators through the soleus muscle can be discarded. In a small percentage of cases however, the musculocutaneous perforators through the soleus are the only ones present. I strongly believe that the misapprehension of this configuration has in the past led to flap failure, giving the skin paddle of the fibula flap a bad reputation. To include this type of perforator, it has to be dissected out of the soleus muscle, all the way up to its vascular origin. Blind inclusion of a soleus muscle cuff does not guarantee that these perforators are preserved. I have had to perform a separate anastomosis in several cases where these perforators

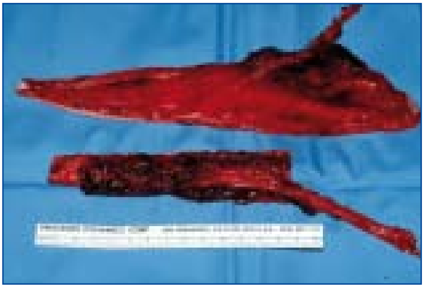


Fig 5

Fig 6

Fig 7

Fig 8

originated cranially of the bifurcation of the peroneal and posterior tibial arteries and thus could not be included in the vascular pedicle of the fibula flap*(fig 5)*.
After selecting the perforator(s) of the skin paddle, the soleus muscle is freed from the part of the fibula that will be included in the flap. The perforator(s) that are vascularising the skin paddle often have muscle branches to the soleus muscle. These can be clipped or ligated *(fig 6)*. Preferably I use titanium microclips throughout the dissection. If necessary, the design of the skin flap can be modified at this stage, to fully include the best perforators. Then the anterior incision in made through skin, subcutis and fascia. The peroneal muscles are freed from the fascia, the septum and the fibula. There is no need to include a muscle cuff of peroneal muscles within the flap. The peroneal muscles have their origin on the septum and the fibula, so a sharp dissection is called for. I use scissors and take care not to damage the periosteum of the fibula. This is important as the blood supply to the bone will change from endosteal to periosteal when the flap is dissected.
The perforators on the dorsal side of the septum will often have branches that perforate through the septum into the peroneal muscles on the anterior side. These branches can be clipped or ligated. If one of these branches is accicentally

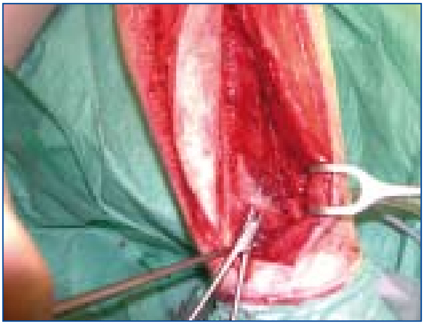


Fig 9

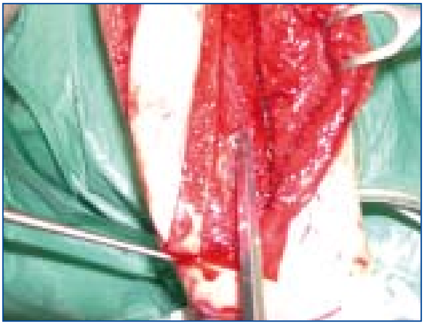


Fig 10

Fig 11

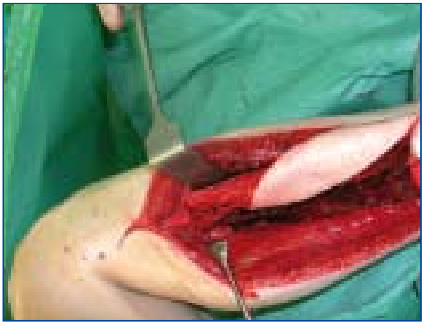


Fig 12

cut close to the septum, it can easily retract behind the septum, making it difficult to control the bleeding. Knowing where the dorsal perforators are will make it easy to find these branches and deal with them without damaging the dorsal perforators. This is an important step. Making mistakes here can seriously endanger the skin paddle.
The anterolateral septum is now reached. This is transsected close to the fibula. Be cautious in the cranial part, where you will find the anterior tibial vessels and the peroneal nerve very close to this septum and to the fibula *(fig 7)*. The extensor muscles of the toes and foot are then dissected off the fibula. Here again you do not want or need a muscle cuff, as the anterior neurovascular bundle is easily damaged. Again scissors are used as not to damage the periosteum. The interosseous membrane now comes into view. This is the moment we will perform the proximal and distal osteotomies. Proximally the peroneal vessels have already been identified and will be not very close to the fibula, making it relatively simple to dissect around the fibula. I prefer a 1cm wide hooked raspartory to do this. I change this for a langenbecks distractor to protect the vascular pedicle and use an oscillating saw to perform the osteotomy *(fig 8)*. The same procedure is used distally. The peroneal vessels are very close to the fibula in this spot, so stay close to the fibula when going around it. Once the fibula has been transsected, it can be pulled out and slightly exorotated using a one toothed hook in the distal opening of the fibula. The interosseous membrane is now transsected close to the fibula and on the dorsal side the fascia of the deep flexor compartment is opened. This is best done over the flexor hallucis longus muscle. These maneuvers will create room to pull out the fibula some 3-4 cm, providing good access to the posterior tibial muscle and the vascular pedicle. This dissection is started distally. The peroneal vessels are located just under the dorsal fascia of the posterior tibial muscle. Once the vessels have been identified they are ligated and transsected *(fig 9)*. Usually the peroneal vessels give off quite a few branches at this spot. These also have to be clipped or ligated and transsected. The posterior tibial muscle is now freed from the fibula and the dorsal fascia is carefully split. All branches to the muscle are clipped and the peroneal vessels are slowly freed *(fig 10)*. A cuff of ½-1cm of posterior tibial muscle is left on the fibula. This will improve the vascularisation of the periosteum and decrease the risk of dissecting accidentally between the fibula and the vascular pedicle of the flap. This dissection upward is the most tedious part of elevating the fibula flap, as many branches to the musculature have to be clipped and transsected. Halfway up the pedicle you will often find a venous connection to the posterior tibial veins. This can be transsected. The motor nerve of the posterior tibial muscle and the flexor hallucis longus muscle run along with the pedicle. The innervation of the posterior tibial muscle can often be spared, at least partially. The flexor hallucis longus muscle however is denervated and devascularised when it is dissected off

the flap and left in situ. This can cause flexture contracture of the great toe1 *(fig 11)*. I therefore usually include the flexor hallucis longus muscle in the flap[2,3]. This makes the dissection shorter and easier and the muscle provides protection to the skin perforators that usually run through it. The muscle will increase the flow in the flap and can be used for soft tissue reconstruction. If you do not want the muscle included, be carefull not to damage the skin perforators when dissecting them out of the muscle.
In the cranial part of the lower leg, the vascular pedicle detaches from the fibula and deviates medially toward the bifurcation with the posterior tibial vessels. In these last centimeters you'll find some big muscular perforators to the soleus muscle. If a a long pedicle is needed, ligate and divide these and continue your dissection up to the posterior tibial artery. If you do not need maximum pedicle length, you can leave the muscle perforators in situ and transsect the pedicle at that point.
Toward the bifurcation of posterior tibial and peroneal artery, the veins will sometimes form a complex pattern of crisscrossing and confluent vessels. This can be difficult to dissect. I usually select the artery and one vein to dissect up to the bifurcation and leave the other veins in situ *(fig 12)*.

Some general remarks

The most reliable skin perforators are situated in the distal part of the flap. One perforator is sufficient for even a large skin paddle. Skin paddles of up to 12x25 cm can easily be elevated with the fibula flap. The donor defect will have to be skin grafted but generally will cause few to no complaints. Allways take out the maximum length of the fibula. This will make your dissection more easy and give you the possibility of lengthening your vascular pedicle by dissecting off the excess of fibula on the proximal side. For reason of maximum pedicle length, always start modeling your reconstruction from the distal end of the fibula. To increase the amount of bone in segmental reconstruction, you can use the fibula as double barrel, triple barrel or even quadruple barrel by performing osteotomies and folding the fibula, leaving the vascular pedicle intact. If you fear for kinking of the vascular pedicle, you can give this some more room by excising 1 cm segments of bone at every bend.

References

1. *Hidalgo DA. Fibula free flap: a new method of mandible reconstruction. Plast Reconstr Surg. 1989 Jul;84(1):71-9.*

1. *Rogers SN, Lakshmiah SR, Narayan B, Lowe D, Brownson P, Brown JS A comparison of the long-term morbidity following deep circumflex iliac and fibula free flaps for reconstruction following head and neck cancer. Plast Reconstr Surg. 112(6):1517-25, 2003*

2. *Hidalgo, D. A., and Rekow, A. A review of 60 consecutive fibula free flap mandible reconstructions. Plast. Reconstr. Surg. 96: 585, 1995.*

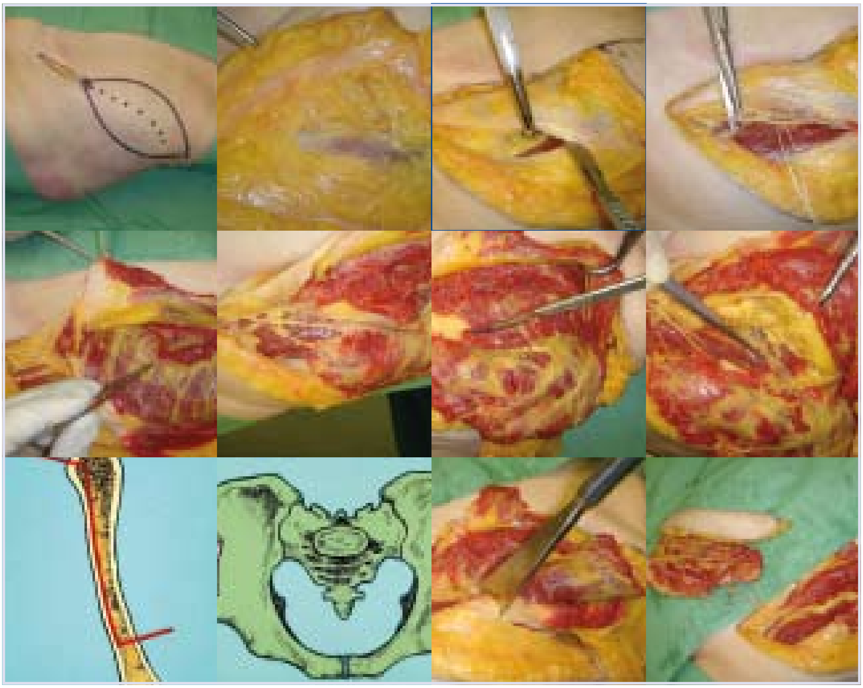
3. *Cordeiro, P. G., Disa, J. J., Hidalgo, D. A., and Hu, Q. Y. Reconstruction of the mandible with osseous free flaps: A 10-year experience with 150 consecutive patients. Plast. Reconstr. Surg. 104: 1314, 1999.*

4. *Winters HA, de Jongh GJ. Reliability of the proximal skin paddle of the osteocutaneous free fibula flap: a prospective clinical study. Plast Reconstr Surg. 1999 Mar;103(3):846-9.*

5. *Klein S, Hage JJ, van der Horst CM, Lagerweij M. Ankle-arm index versus angiography for the preassessment of the fibula free flap. Plast Reconstr Surg. 2003 Feb;111(2):735-43.*

11

The osteo-myocutaneous iliac crest flap; How I do it



11 The osteo-myocutaneous iliac crest flap; How I do it

Introduction

The iliac crest flap was one of the first free vascularized bone flaps on the "market" It was popularized for mandibular reconstruction by Urken, Brown and others in the late eighties and early nineties[1,2,3]. In recent years the iliac crest flap has lost some of its popularity to the free vascularized fibula flap, the fibula being superior in compression strength, available length and donor site morbidity. Also acceptor site morbidity is less when used for mandibular reconstruction. However, the free vascularised Iliac crest flap remains an excellent flap for various bony reconstructions. Donorsite morbidity can be controlled by technical modifications and the possibility to include the internal oblique abdominal muscle makes it first choice for maxilla reconstruction in many cases[4,5]. For these reasons I feel the free vascularised iliac crest flap should be in every reconstructive surgeon's armamentary.

The flap can be raised as an osteo musculo cutaneous flap. The skin paddle can be large, (10x25 cm) and still the donorsite can be closed primarily in most cases. The skin is not very supple and the layer of subcutaneous fat is often thick. Also the mobility of the skin paddle is limited due to its close relation to the iliac crest. For these reasons it's better not to use the skin paddle for intra oral reconstruction when a mandibula or maxilla reconstruction is performed. However, the skin paddle is well situated for reconstructions of extra oral defects in combination with mandibula or maxilla reconstruction. The muscular part of the flap is the internal oblique abdominal muscle. This muscle derives it vascular supply from the ascending branch of the DCIA. The entire muscle can be included in the flap and is very usefull for reconstruction of intra oral and intra nasal defects.

Pre-operative work up

Contra indications will mostly be because of locoregional operations. When the iliac crest has previously been used as donorsite for non vascularised bone, the use of the same iliac crest as free vascularized bone graft is probably not possible and should not be considered.

A history of vascular disease will not automatically render the iliac crest flap useless. It can even be a good alternative when the fibula flap is not available because of vascular disease. When the external iliac artery is heavily affected, it is difficult to predict the condition of the deep circumflex iliac artery. In these cases a selective angiography may be performed to provide more information. We have no experience with duplex as pre operative test for the deep circumflex iliac artery.

Positioning

the flap can be dissected best with the patient in lateral-supine position. Due to the fact that the reconstruction is often in the head and neck region, the patient will mostly be in the supine position. In this case the pelvis should be raised on the selected side. The operating field runs from the pubic tuber to the lower ribs. To provide good access to the iliac crest, the ipsilateral arm should be out of the way. This can be achieved in several ways; The arm can be abducted, or pulled across the thorax to the contralateral side. If the pelvis can be raised enough to the enable the arm to be tucked alongside the body without being in the way, this is also an option.

Surgical technique

The incision runs along the inguinal ligament to the anterior superior iliac spine and is continued along the iliac crest *(fig 1)*. If a skin paddle is needed, this is centered over the iliac crest and raised in a plane just superficial to the fascia of the abdominal and gluteal muscles. The perforators that supply the skin paddle run just over the top of the iliac crest, through the abdominal muscles *(fig2)*. These should be spared and included in the flap. These perforators do

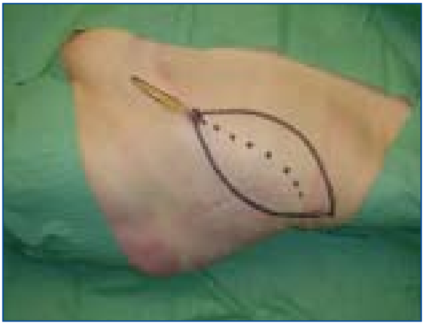


Fig 1

Fig 2

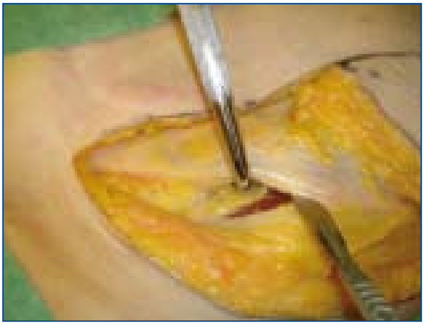


Fig 3

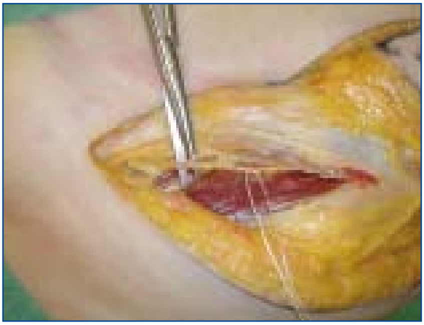


Fig 4

not have to be dissected. Just include a cuff of external oblique abdominal muscle and leave the subcutaneous tissue attached to it. If no skin paddle is needed, The skin and subcutaneous tissue can be dissected off the external oblique muscle untill the iliac crest is reached. Especially in the male, there can be significant bulging of the muscle, creating an 'overhang' over the edge of the iliac crest. This should be followed till the iliac crest is reached. The external oblique shoud be transsected close to the iliac crest, leaving the aponeurotic part attached to the muscle to facilitate closure. The inguinal ligament can be freed completely from the anterior superior iliac spine *(fig 3)*. Take care not to damage the lateral cutaneous femoral nerve. The inguinal ligament and the external oblique abdominal muscle can now be retracted cranially. The fascia on the underside of the inguinal ligament is opened and the vascular pedicle is identified and carefully dissected *(fig 4)*. The pedicle will run into the iliac muscle just lateral of the A.S.I.S. No dissection beyond this point is needed, as a cuff of iliac muscle will be included in the flap to protect the vascular pedicle. The ascending branch of the D.C.I.A. normally branches of the main pedicle 1 cm medially of the A.S.I.S. This however is not very reliable, and the ascending branch may run parallel to the main pedicle right

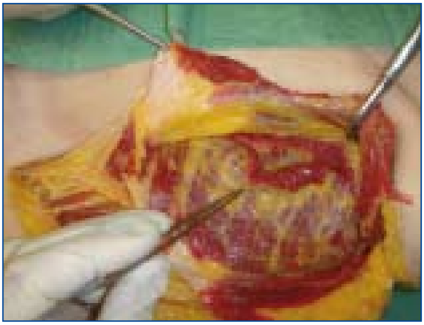


Fig5

Fig 6

Fig 7

Fig 8

up to the iliac vessels. Therefore; When dissecting the D.C.I.A. don't clip or ligate any branches until you are 100% shure that it's not the ascending branch. After the pedicle has been dissected, the external oblique muscle is dissected off the internal oblique and retracted cranially. This can continue up to the ribs. In obese or very muscular people, this may require a strong hand at the retractor. The internal oblique muscle is transsected *(fig 5)* and The dissection is continued on the inside of the internal oblique muscle in a caudal direction, freeing it off the transverse abdominal muscle. The ascending branch runs on the inside of the internal oblique muscle and should be included in the flap. The muscle is detached from the rectus sheath on the medial side. Avoid opening the rectus sheath. When the dissection of the internal oblique muscle is comleted, the vascular situation becomes clear *(fig 6)*. The ascending branch is followed to its origin and included in the flap. The transverse abdominal muscle is now transsected, leaving a 1 cm muscle cuff on the iliac crest *(fig 7)*. We now are in the pre-peritoneal plane. This is a very lose avascular plane and the pre-peritoneal fat can easily be wiped off the iliac muscle on the inside of the pelvis. 10 to 12 cm dorsally of the A.S.I.S. the iliac branch of the iliolumbar artery can be found *(fig 8)*. This runs perpendicular to the iliac crest, right on

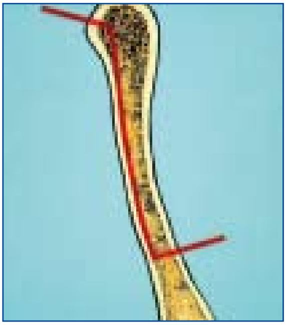


Fig 9a

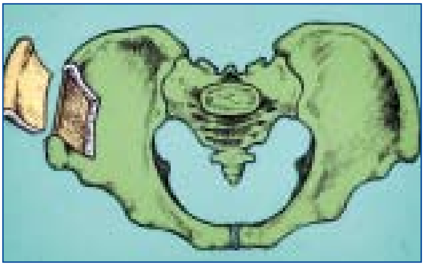


Fig 9b

Fig 10

Fig 11

top of the iliac muscle and can be dissected very easily. This artery and its veins can be used as an additional or alternative pedicle for the iliac crest flap[6,7]. The length of this pedicle generally will be around 6 cm. As the dissection of this pedicle hardly takes any time, I normally include it for safety reasons.
Now the position of the osteotomies is determined. Whenever possible, I try to use a bi-cortical bonegraft, and leave the outer table in situ *(fig 9a,b)*. First the inner table is osteotomized. A cuff of iliac muscle is left on the inner table to protect the vascular pedicle. The inner table is osteotomized perpendicular to the iliac crest, starting at 1-2 cm. dorsally of the A.S.I.S., leaving the A.S.I.S. in situ[4] *(fig 10)*. Both oscillating saw and osteotome can be used. The bony incision runs through the inner table and iliac crest and stops when the outer table is reached. This can be felt easily with both methods. The tricky spot is the anterior incision, where the osteotomy runs under the vascular pedicle. Not damaging the vascular pedicle is crucial at this stage. After completing the parallel- and the dorsal perpendicular osteotomy, the inner table incisions are now completed. The last osteotomy runs over the lateral part of the iliac crest, about 4-5 mm. from the lateral edge. The saw or osteotome follows the inside of the outer table until the desired depth is reached. All osteotomies being completed, the flap can now be lifted *(fig 11)*. This provides us with a strong bicortical bonegraft, 2 cm. wide in the anterior part, narrowing to 5 mm. in the dorsal portion of the flap, Only the outer table will remain in situ. The length of the bony part of the flap can be up to15 cm. The thickness and quality of the dorsal part of the graft will be far less than that of the anterior part, and also the circulation will decrease moving dorsally, especially when osteotomies are performed. This should be taken into consideration when flap choice is discussed.
When a tri-cortical bonegraft is needed, the gluteus muscles are detached from the outer table, and osteotomies are performed through all layers at once, starting with the anterior incision. For these osteotomies I prefer an oscillating saw over an osteotome, as the risk of unwanted fractures or even splintering is substantial when using an osteotome.

Donorsite Closure

The bony donorsite is likely to produce substancial bleeding. This can be dealt with by application of local coagulants like willospon[R]. A drain is left before further closure of the abdominal wall. Apart from prevention of haematome formation, this drain can be used for local analgesia, by instillation of 20 cc bipuvacain 0,5% every 8 hours for the first days. The drain should be kept closed for 30 to 60 minutes after the instillation of the bipuvacain, before the vacuum is put on again.
Closure of the abdominal wall is facilitated by leaving the A.S.I.S. in situ.
This also greatly reduces the contour deformity. The inguinal ligament can

be re-attached to the A.S.I.S. with one key stitch. The rest of the abdominal muscles can be closed in one layer. I use a PDS loop running suture to re-attach the transverse- and external oblique abdominal muscle. The fibrous origin of the gluteal muscles gives your sutures a better hold than the fragile remaining bone, so I do not bother to make holes in the bone for suturing. In case of a full thickness (tri-cortical) bonegraft, a non-resorbable mesh graft on the inside of the abdominal wall (pre-peritoneal) does help to reduce donorsite morbidity [4]. Walking can be painfull for several months and femoral nerve palsy is sometimes observed. Further donorsite morbidity can be; abdominal bulging / loss of contour; abdominal herniation / incarceration and persisting pain[8].

The iliac crest used for maxilla reconstruction

The iliac crest provides well vascularised bone. One of its best features is that it can be completely covered by a wrap around internal oblique abdominal muscle flap based on the same vascular pedicle. This makes it very suitable for maxilla reconstruction, where both oral and nasal lining are needed. After it has atrophied, the muscle provides a relatively thin well adherent lining that does not sag, as skin flaps are likely to do. The muscle does not need to be skin grafted, as the oral and nasal mucosa will seed onto the muscle/fascia providing adequate mucosal lining within some weeks. The internal oblique muscle can also be used for reconstruction of defects of the bony palate. This muscle flap is likely to contract, especially when there is no dorsal portion of the bony palate left. In these cases, insufficient oro-nasal closure can easily occur. Patients with an intact distal soft palate often have an adequate function with an obturator. When the maxilla and palate have been reconstructed with an iliac crest/internal oblique flap, the resulting problems with speech and fluid intake may be worse than they were with the obturator before the reconstruction. A pharingoplasty will be needed to restore function in these cases. This should be taken into consideration when planning a maxilla reconstruction.

The 3-dimensional shape of the complete maxilla is difficult, if not impossible, to reconstruct with any available free vascularised bone flap. The lower orbital rim and the zygomatic arch greatly determine the contour of the cheek and the lateral aspect of the face. The alveolar process is important for dental rehabilitation and provides support for the upper lip and the nose, thereby determining the form of the central part of the face. The arch formed by the alveolar process and the arch formed by the zygomatic bone and the lower orbital rim have a different radius and a different center. They also lie in different horizontal planes. In maxilla reconstruction the focus normally is on one of these two arches, depending on the type of defect involved. In type 1 (central defect) and type 2 (hemi maxillectomy with intact orbital floor and lower orbital rim) The emphasis is on reconstruction of the alveolar process.

We feel these defects can best be reconstructed with a vertical/oblique positioning of the iliac crest flap. The iliac crest forming the alveolar process and the monocortical extension of the flap (inner table of the iliac bone) forming the hard palate. The internal oblique muscle is wrapped around the bone to provide well vascuarised cover and reconstruct remaining defects in the bony palate. When the maxillectomy defect includes the orbital floor (type 3) the emphasis in reconstruction will be on restoring cheek contour. In these cases the iliac crest is placed in a horizontal position to reconstruct the lower orbital rim and the zygomatic arch. The monocortical extension (inner table of the iliac bone) runs dorsally to form the orbital floor, supporting the eye (type 3a) or a future prosthesis (type 3b). To also reconstruct the alveolar process in these cases, we use unvascularised bone to form a bone block that is screwed onto the vascularised part in the correct position. All bone, vascularised and unvascularised is then covered with a wrap around internal oblique muscle flap, that can also be used to reconstruct the bony palate. Reconstruction of the alveolar process in these cases can also be performed as a secondary procedure. It is advisable to do this in cases where radiotherapy is needed after the maxilla reconstruction.

References

1. *Urken ML, Vickery C, Weinberg H, Buchbinder D, Biller HF. The internal oblique-iliac crest osseomyocutaneous microvascular free flap in head and neck reconstruction. J Reconstr Microsurg. 1989 Jul;5(3):203-14; discussion 215-6.*

2. *Urken ML, Weinberg H, Vickery C, Buchbinder D, Biller HF. Using the iliac crest free flap. Plast Reconstr Surg. 1990 Jun;85(6):1001-2.*

3. *Brown, J. S. Deep circumflex iliac artery free flap with internal oblique muscle as a new method of immediate reconstruction of maxillectomy defect. Head Neck 18: 412, 1996.*

4. *H. A. H. Winters, L. E. Smeele. Reduction of donor site morbidity of the iliac crest free flap by preservation of the anterior superior iliac spine. European Journal of Plastic Surgery, Volume 23, Issue 4, May 2000, Pages 183 – 184.*

5. *H. A. H. Winters, S. M. van Harten. Maxillary reconstruction using a horizontally placed iliac crest flap. European Journal of Plastic Surgery, Volume 25, Issue 7 - 8, Feb 2003, Pages 410 – 414.*

6. *Winters HA, Smeele LE, Leemans CR. The bipedicled iliac crest flap. J Reconstr Microsurg. 1996 May;12(4):257-9.*

7. *Winters HA, van Harten SM, van Royen BJ. The iliolumbar artery as the nutrient pedicle for an iliac crest graft: a new technique in reconstruction of the lumbar spine. Plast Reconstr Surg. 2002 Jan;109(1):249-52.*

8. *Hartman EH, Spauwen PH, Jansen JA. Donor-site complications in vascularized bone flap surgery. J Invest Surg. 2002 Jul-Aug;15(4):185-97.*

12

considerations for the future

12 considerations for the future

What is the future for reconstructive microsurgery?

There are several fields in which this development will take place. The search for technical refinements in autologeous tissue transfer will continue. In the near future, the majority of research and papers will still be focusing on this aspect. Reduction of donorsite morbidity and the improvement of functional outcome at the acceptorsite are the main goals in this field. This thesis is by no means the end of my involvement in the chase of these goals. At this moment we are working on several aspects of microvascular reconstruction in our department and hospital.

The combination of vascularised and non-vascularised bone looks very promising in patients who do not have to undergo radiotherapy post-operatively. Using the surplus of fibula as a non vascularised onlay bonegraft can improve the contour of the jaw in mandibula reconstruction and provide a better base for implants – and thus for dental rehabilitation – at the same time. In reconstruction of the long bones, the use of an avascular allograft or synthetic Ca-trifosfate prosthesis in combination with an intramedullary placed vascularised autograft can result in better fixation, greater initial stability and earlier load bearing, because creeping substitution will not only be from the ends but over the entire length of the graft. In maxilla reconstruction, the 3-dimensional shape of the maxilla provides a major challenge. The addition of non vascularised autologeous bone from the same donorsite as the vascularised bonegraft can greatly improve the result by creating the possibility to not only reconstruct the orbital rim and the zygomatic arch, thereby improving contour, but also to reconstruct the alveolar process for future dental rehabilitation. There are more aspects of maxilla reconstruction that may be improved in the near future; the choice and placement of flaps for the different types of defects; the way to create a thin adherent lining; pro's and con's of primary and secondary reconstruction.

Apart from refining the techniques for autologeous tissue transfer, there will be an increasing interest in allotransplantation. Hand, lower arm and –recently- face have already been successfully transplanted from one human being to another. At this moment, the consequences are considerable. Immunosupression is mandatory and can lead to catastrophic complications. Research will mainly focus on this aspect in the near and slightly more distant future. Will it be possible to manipulate the tissue to be transplanted in a way that makes it immunocompatible?, or maybe only in a way that will cause less immunoresponse? Maybe genetic manipulation of the acceptorperson is possible so the allotransplant is accepted without disabling the reaction to infections.

The more distant future will maybe see microvascular xenotransplantation. Also in this form of tissue transfer –from animals to humans- immunocompatibility

is the major factor. Maybe genetic engineering will enable us to manipulate animals to the extend of being immunocompatible. Transgenic animals already exist. Genetically engineered pigs produce human insulin. Will there be a time where every human being has one or more –genetically manipulated- animals ready to serve as tissue or organ donor? Will this be an animal with the specific antigenic structure of one single human being, or will we be able to develop an animal that can serve as a universal donor to humans?
Obviously allotransplantation and certainly xenotransplantation does raise a lot of ethical questions. Transplantation of kidneys, livers, hearts and lungs is accepted in most societies. This can not be said for transplantation of items that are recognizable on the outside; hands and especially faces. When genetic engineering is added to improve immunocompatibility, the ethical issue becomes a lot bigger. It is beyond the scope of this thesis to discuss all these issues, but it looks like the future of reconstructive surgery will be very interesting. Apart from the scientific development of healthcare, there is also a socio-economical side to it. Factors like the cost of free vascularised reconstructions and the availability of skilled personnel are increasingly important in healthcare. The policy of government, insurance companies and hospital management is not necessarily directed toward maximum quality treatment for every individual patient. In this perspective, high-tech, high cost, time consuming state of the art reconstructive surgery is not high on their priority list. This may be rather influential in the way medicine will develop in the future. We will find out in the years to come.

Addendum: Letter to the editor

H.A.H. Winters

"The thoracic duct as a venous receptor vessel for free flap transplantation"
Plast. Reconstr. Surg. 1998; 101(3):872-3.

Sir,

A 31 year old man suffered from severe collaps of thoracic vertebrae, resulting in debilitating kyphosis. Anterior release of the thoracic spine was performed through a leftsided thoracotomy. A 28 cm. fibular free flap was harvested from the left leg, osteotomised in the middle, folded in two and wedged into a slot in the vertebral corpora, thus stabilising the re-erected spine. The seventh costal artery was anastomosed end to end to the fibular artery. The fibular vein was to be anastomosed to the hemi azygos vein but, unfortunately, the latter was not available. For technical reasons the azygos vein and the inferior vena cava could not be reached. Lacking any other means of venous return, we decided to use the thoracic duct. An end to side anastomosis was performed using 9-0 nylon running sutures. After removing the clamps of the acceptor vessels an adequate flow was estabished, the thoracic duct showing a cranially directed bloodflow. Uneventfull healing followed. Although angiography has not been performed, a strong bony incorporation of the fibula, indicative of viability, was visible on a C.T. scan 6 months postoperatively.
I do not advocate the routine use of the thoracic duct for a venous receptor in free flap surgery. However, in cases where no adequate receptor vein is available, the use of the thoracic duct - even though unorthodox - may offer a solution.

Henri A. H. Winters, M.D.

List of additional literature

This thesis is based on the experience of the author from 12 years of performing free vascularized bone transplants. However, not all publications by the author on this subject are included in this thesis. The list below shows the publications on the subject that were not included

- *R.J.P. Noorda; P.I.J.M. Wuisman; A.J. Kummer; H.A.H. Winters; J.F. Ploegmakers "Non-functioning malignant paraganglioma of the posterior mediastinum with spinal cord compression" Spine, vol. 21, no 14, 1703-1709 (1996)*

- *L.E. Smeele, O.S. Hoekstra, H.A.H. Winters, C. R. Leemans, "Clinical effectiveness of 99mTc-diphosphonate scintigraphy of revascularised iliac crest flaps" Int. J. Oral Maxillofac. surg. 25; 366-369 (1996)*

- *L.E. Smeele, Ch. R. Leemans, H.A.H. Winters, " Reconstructieve mogelijkheden na tumorchirurgie in het hoofd-hals Gebied", Ned. Tijdschr. Tandheelkd. 103; 358-360 (1996)*

- *C.R. Leemans, H.A.H. Winters, L.E. Smeele, "Reconstructie van grote defecten na resecties voor hoofd-hals tumoren met vrije huid-, bot- en spier-lappen", Ned Tijdschr Geneeskd 1996; 140: 689*

- *R.J. Noorda, P.I. Wuisman, A.J. Kummer, H.A.H. Winters, J.A. Rauwerda, S.M. Egeler-Peerdeman, "Nonfunctioning malignant paraganglioma of the posterior mediastinum with spinal cord compression. A case report. Spine 1996; 21(14):1703-9*

- *E.A. Nijland, M.P. van den Berg, P.I.J.M. Wuisman, B.J. van Royen, H.A.H. Winters, W.J.R. van Ouwekerk, "Correction of a dystrophic c ervicothoracic spine deformity in Recklinghausens disease", Clinical Orthopedics and Related Research; nr 349; pp. 149-55*

- *P.I. Wuisman, T.U. Jiya, M. Van Dijk, S. Sugihara, B.J. van Royen, H.A.H. Winters "Free vascularised bone graft in spinal surgery: indications and outcome in eight cases", Eur Spine J 1999;8(4):296-303*

- *M. Van Dijk, H.A.H. Winters, P.I. Wuisman, "Recurrent osteoblastoma of the hamate bone. A two stage reconstruction with a free vascularised iliac crest flap", J. Hand Surg [Br] 1999;24(4):501-5*

- *R.J. Noorda, P.I. Wuisman, M.W. Fidler, P.T. Lips, H.A. Winters, "Severe progressive osteoporotic spine deformity with cardiopulmonary impairment in a young patient. A case report", Spine 1999; 24(5):489-92*

- *H. Mast, E.A.J.M. Schulten, H.A.H. Winters I. van der Waal, "Een zwelling in het onderfront berustend op een ossificerend fibroom", Nederlands Tijdschrift voor Tandheelkunde 2005; 112: 394-5*

- *Hai Hu, H.A. Winters, R.M. Paul, P.I. Wuisman, "Internal Thoracic vessels used as pediclegraft for anastomosis with vascularized bone graft to reconstruct C7-T3 spinal defects: a new technique", Spine 2007; 32(5):601-5*

Summary

Chapter 1

Introduction

In chapter one the theme of this thesis is outlined against the history of microvascular reconstructive surgery. A short overview of available free vascularised osseous flaps is given.

Chapter 2

“Reliability of the proximal skin paddle of the osteocutaneous free fibula flap: a prospective clinical study” Plast. Reconstr. Surg.1999;103(3):846-9

The clinical consequences of the exact position and trajectory of the skin perforators in the free osteocutaneous fibula flap are discussed; Perforators that run through the flexor hallucis longus muscle go straight to the peroneal vessels. Perforators that run through the soleus muscle often run cranially and branch off proximally from the peroneal vessels. The clinical consequences of these findings are discussed.

Chapter 3

“Fibula free flap phalloplasty: modifications and recommendations” Microsurgery 1996; 17(7):358-65

The design of the fibula flap for phalloplasty is modified in a way that a longitudinal flap is taken. This provides for better sensibility and more skin perforators, thus better vascular reliability.

Chapter 4

"The bi-pedicled iliac crest flap" J Reconstr Microsurg 1996; 12(4):257-9

The iliac branches of the iliolumbar artery and vein provide an additional and alternative vascular pedicle for the iliac crest flap.

Chapter 5

“The iliolumbar artery as the nutrient pedicle for an iliac crest graft: a new technique in reconstruction of the lumbar spine” Plast Reconstr Surg 2002; 109(1):249-52

Clinical application of the vascular pedicle described in chapter 4 for spinal reconstruction. A case is described where the iliac crest has been used –pedicled on the iliolumbar vessels- for reconstruction of the lumbar spine.

Chapter 6

"Reduction of donorsite morbidity of the iliac crest free flap by preservation of the anterior superior iliac spine" Eur J Plast Surg 2000; 23(4):183-184

Preservation of the anterior superior iliac spine and use of a bi-cortical graft instead of a tri-cortical graft are important factors in the reduction of donorsite morbidity in the iliac crest flap

Chapter 7

"Maxilla reconstruction using a horizontally placed free iliac crest flap"
Eur J Plast Surg 2003; 25(7-8): 410-14

The advantages and disadvantages of a horizontally placed iliac crest flap are discussed, considering the type of maxillectomy defect. For a type IIIa defect the use of a horizontally placed iliac crest flap is advocated

Chapter 8

"A comparison between fibula and iliac crest in mandibular reconstruction"
Eur J. Plast Surg 2007; 29(5):205-8

Two groups of patients that underwent a mandibula reconstruction with either free fibula or free iliac crest -all operated by the same surgeon- are compared in aspects of flap failure, complications and morbidity of both acceptorsite and donorsite. Statistical analysis shows the fibula flap to be superior in terms of donorsite and acceptorsite morbidity.

Chapter 9

"The use of free vascularized bone grafts in spinal reconstruction"
Submitted for publication

The reconstruction of spinal defects or instability with free vascularized bone grafts is not a common technique at this moment. The reconstructive surgeon that faces a spinal reconstruction has to decide which flap to take, how to approach the defect and where to find adequate acceptor vessels. Based on our experience in 23 cases, we describe the use of free fibula and iliac crest flaps in spinal surgery from the reconstructive surgeons point of view. In one of these cases we failed to vascularize the bone graft for lack of acceptor vessels, in the remaining 22 cases, revascularization was successful.
The initial disease will greatly dictate the extend of the final defect and at least part of the approach, especially when a malignant tumor has to be removed. Special attention is paid to the dissection and use of acceptorvessels for lumbar, thoracic and cervical reconstructions. Tricks and pitfalls are discussed for anterior, dorsal, thoracolumbar, lumbar and trans-sternal approaches.

Chapter 10 and 11: "how I do it; Fibula and Iliac crest"

In these two chapters the author has tried to combine experience and literature into an elaborate description of the two most used free vascularized bone transplants. Every tip and trick known to the author is included. These two chapters are the authors hope that at least part of this thesis may actually be read by someone.

Chapter 12:

"future aspects"

This chapter contains the authors view of the development of reconstructive surgery and osseous reconstructive surgery in particular. Possible short term refinements in existing techniques are described and some thoughts on the development in tissue engineering, allo- and xenotransplantation are discussed.

Nederlandse Samenvatting

Gevasculariseerd bot van fibula en crista iliaca; de ervaring van één chirurg gedurende meer dan 10 jaar.

Hoofdstuk 1

Introductie

In hoofdstuk een wordt - vanuit een historisch kader - een kort overzicht gegeven van de ontwikkeling van de reconstructieve microchirurgie in het algemeen, alsmede van de bestaande gevasculariseerde ossale lappen. Ook wordt aangegeven hoe dit proefschrift tegen de achtergrond van deze ontwikkeling gezien moet worden.

Hoofdstuk 2

"Reliability of the proximal skin paddle of the osteocutaneous free fibula flap: a prospective clinical study" Plast. Reconstr. Surg. 1999;103(3):846-9

De klinische consequenties van de exacte positie en het verloop van de huid perforatoren in de osteocutane fibula lap worden besproken. Huidperforatoren die door de musculus flexor hallucis longus lopen gaan vrijwel altijd direct naar de peroneale vaten. Perforatoren die door de musculus soleus lopen hebben vaak een duidelijk verloop naar craniaal en monden regelmatig boven de oorsprong van de arteria en vena peronea uit. De consequenties voor de dissectie en het gebruik van de fibula lap worden besproken.

Hoofdstuk 3

"Fibula free flap phalloplasty: modifications and recommendations" Microsurgery 1996; 17(7):358-65

Het ontwerp van de fibula lap ten behoeve van de phalloplastiek wordt aangepast ten opzichte van de eerdere literatuur hierover. Het huideiland wordt in de lengterichting van het onderbeen geprojecteerd. Hierdoor zijn weliswaar twee naden nodig, maar de vascularisatie verbeterd en wordt betrouwbaarder omdat er meer perforatoren in de lap zitten. Ook zal de sensibiliteit verbeteren vanwege de betere projectie van de oppervlakkige zenuwen.

Hoofdstuk 4

"The bi-pedicled iliac crest flap" J Reconstr Microsurg 1996; 12(4):257-9

De iliacale taken van de arteria en vena iliolumbalis vormen een aanvullende en/of alternatieve vaatsteel voor de crista iliaca lap. De anatomie en de klinische consequenties worden besproken.

Hoofdstuk 5

"The iliolumbar artery as the nutrient pedicle for an iliac crest graft: a new technique in reconstruction of the lumbar spine"
Plast Reconstr Surg 2002; 109(1):249-52
De klinische toepassing van de alternatieve vaatsteel voor de crista iliaca zoals die in hoofdstuk 4 wordt beschreven. Een voorbeeld van reconstructie van de lumbale wervelkolom met behulp van een op deze vaatsteel gesteelde crista iliaca wordt gegeven.

Hoofdstuk 6

"Reduction of donorsite morbidity of the iliac crest free flap by preservation of the anterior superior iliac spine" Eur J Plast Surg 2000; 23(4):183-184
Het sparen van de spina iliaca anterior superior bij de dissectie van een crista iliaca lap alsmede het gebruik van een bi-corticale in plaats van een tri-corticale lap zijn belangrijke factoren bij het beperken van de donorsite morbiditeit van de crista iliaca lap.

Hoofdstuk 7

"Maxilla reconstruction using a horizontally placed free iliac crest flap"
Eur J Plast Surg 2003; 25(7-8): 410-14
De voor- en nadelen van een horizontal geplaatste crista iliaca lap voor reconstructie van de mandibula -specifiek IIIa defecten- worden besproken.

Hoofdstuk 8

"A comparison between fibula and iliac crest in mandibular reconstruction"
Eur J. Plast Surg 2007; 29(5):205-8
Twee groepen patiënten worden vergeleken na een reconstructie van de onderkaak. De groep waarbij de fibula lap gebruikt werd wordt vergeleken met de groep waarbij de crista iliaca lap gebruikt werd. Er wordt gekeken naar overleving van de lap, complicaties en morbiditeit op zowel donor- als acceptorplaats. Statistische analyse laat zien dat de fibula lap zowel met betrekking tot donorsite als acceptorsite scoort.

Hoofdstuk 9

"The use of free vascularized bone grafts in spinal reconstruction"
Ter publicatie aangeboden
De reconstructie van een defect van de wervelkolom met een vrij gevascularizeerd bottransplantaat is een zeldzame operatie. De reconstructieve chirurg die zo'n operatie uit moet voeren zal moeten beslissen welk bottransplantaat het meest geschikt is, welke toegang hij zal kiezen en wat de meest geschikte acceptorvaten zijn. Op basis van onze ervaring bij 23 patiënten wordt het gebruik van de gevasculariseerde vrije fibula en de crista iliaca in de wervelkolom beschreven.

De onderliggende aandoening zal grotendeels de maat en de ligging van het defect bepalen alsmede de beste toegangsweg. Vooral de chirurgisch-technische aspecten van de ingreep worden belicht, met speciale aandacht voor de keuze en dissectie van de acceptorvaten bij cervicale, thoracale en lumbale reconstructies.

Hoofdstuk 10 en 11

"how I do it; Fibula and Iliac crest"
In deze twee hoofdstukken wordt een uitgebreide beschrijving gegeven van het vrijprepareren van de fibula- en de crista iliaca lap. Hierin worden literatuur en ervaring bijeengebracht in gedetailleerde adviezen. Deze twee hoofdstukken vertegenwoordigen de hoop van de auteur dat mogelijk een deel van dit proefschrift daadwerkelijk gelezen zal worden.

Hoofdstuk 12

"future aspects"
De verwachtingen van de auteur ten aanzien van de ontwikkelingen in de toekomst, zowel in de zin van verbeteringen aan de bestaande reconstructiemethoden op korte termijn, alsook in de vorm van ontwikkelingen op het gebied van tissue engineering, allo- en xenotransplantaties.

Dankwoord

Los van het feit dat ik het erg leuk vind om de eerste promovendus van mijn maat Marco te zijn, en aangezien Marion van het hele gebeuren eigenlijk weinig last heeft gehad, zodat het gebruikelijke verhaal daarover eigenlijk achterwege kan blijven, wil ik mij niet wagen aan het componeren van ellenlange lijsten met mensen die bedankt moeten worden, waarbij toch altijd iemand wordt overgeslagen. Daarom houd ik het kort: Iedereen die op enige wijze een steentje aan de totstandkoming van dit proefschrift heeft bijgedragen: Bedankt!
Alle vrienden, familie, collega's etc. die niets met dit proefschrift te maken hebben gehad en die dus voor de zo noodzakelijke balans in mijn leven hebben gezorgd: Ook bedankt!

Curriculum vitae

Hay Winters is in 1957 geboren in venlo. Na de plaatselijke lagere (st. Martinusschool) en middelbare school (st. Thomascollege) te hebben doorlopen werd hij in 1976 uitgeloot voor de studie geneeskunde in Nederland en trok derhalve naar Gent (B) om daar toch met de medicijnstudie te beginnen. In 1977 lootte hij alsnog in en moest opnieuw beginnen in Nijmegen. In 1985 werd het artsexamen behaald en na een klein intermezzo als ARBO deskundige in een bedrijf voor printplaten begon hij in februari 1986 als AGNIO algemene chirurgie in het Diaconessenhuis te Eindhoven. Begin1988 verkreeg hij de toezegging voor de opleiding tot plastisch chirurg van Prof. Dr. F.G. Bouman. In juni van dat jaar werd begonnen met het algemeen chirurgische deel van de opleiding in het st. Lucas ziekenhuis te Amsterdam (opleider Dr. J.N. Keeman). In 1991 werd de opleiding voortgezet in het academisch ziekenhuis Vrije Universiteit te Amsterdam (opleiders Prof.Dr. J. Bloem; Prof. Dr. F.G. Bouman; Prof. Dr. J.W. Mulder).
Na het voltooien van de opleiding in 1994 bleef hij als staflid in het AZVU (thans VU medisch centrum) werkzaam, met de reconstructieve chirurgie als aandachtsgebied.
Naast de Plastische chirurgie op academisch niveau beoefend de auteur ook jaarlijks gedurende enkele weken zijn vak in ontwikkelingslanden. Dit met name voor stichtingen zoals Interplast en de Nederlandse Noma stichting.
Voor de hoognodige balans in het leven zorgen zijn levensgezellin Marion en de nodige hobby's, waarbinnen vooral het zeilen en skiën niet mogen ontbreken. De zeilsport wordt al sinds 1968 in wedstrijdvorm bedreven, waarbij vele nationale en internationale titels in de wacht werden gesleept.